Stenhouse, Gordon Robert Ernest (2019) ***Zooarchaeological analysis of animal resources in the Upper Mun River Valley, Northeast Thailand.*** **PhD Thesis, James Cook University.**

https://doi.org/10.25903/exts%2Dsr71

Zooarchaeological analysis of animal resources in the Upper Mun River Valley, Northeast Thailand

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Submitted in partial fulfilment of the requirements for the degree of Doctor of
Philosophy in the College of Arts, Social Sciences, and Education
of James Cook University

2019

Frontispiece: A traditional Thai deer hunting method, wearing antlers to stalk a herd of deer (Lekagul, 1954)

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Acknowledgements

My first trip to northeast Thailand, after completing my undergraduate degree with my now supervisor Dr Nigel Chang, was an amazing experience. Nigel was the first person to introduce me to archaeology in Southeast Asia, and gave me my first opportunity in the region. During this trip I learnt more about how people utilised different resources, from the rice field snails we ate at lunch, to the hunting of rat and small birds with pellet bows and snares. It was this knowledge that set me on the path of my PhD research.

This research would not have been possible without the help of many people for whom I am very grateful. I would firstly like to thank my supervisors Dr Nigel Chang, Associate Professor Kate Domett, and Dr James Moloney for their support and guidance throughout my doctorate research, particularly in conducting field research, reviewing drafts, and providing expertise on the local fauna within my study area. I would also like to thank Dr Rachanie Thosarat and Chanakarn Hongthong for teaching me how to identify animal remains and allowing me access to their extensive comparative collection.

I would also like to acknowledge the Kingdom of Thailand and the Thai Fine Arts Department for allowing my archaeological research to be conducted in Thailand. The people of Ban Non Wat and the sub-district of Phon Songkhram where my study was based welcomed me into their lives and made me a home away from home.

Additionally, I appreciate the ongoing support from PhD researcher Puangtip Kerdsap (Tip) and research assistant Pimpicha Bannanurak (Mon). Mon assisted greatly with organising accommodation and supporting me whilst in the field. Tip helped greatly with translating documents from Thai to English, and transportation in Thailand. Tip's wealth of knowledge on Thai culture and anthropology was incredibly useful for my research.

Finally, a special thank you to my family and friends, especially to my mum Fay and dad John, who have supported me throughout my studies. You have always been an inspiration to me and I can honestly say that is was your interest in travel, geology, the natural world, and ancient history that drove me to pursue archaeology. I still remember all of the archaeological sites we visited as kids on our many travels. Also to my brother Rowan and sister Iona thank you for your constant help and encouragement throughout my degree. A special thank you has to go my partner Caitlin Evans. We started this journey together as undergrads and you have always been there with support and encouragement.

Statement of the Contribution of Others

Nature of assistance	Contribution
Initial excavation resources	The Society and Environment Before Angkor project
Supervision	Dr Nigel Chang (JCU) Associate Professor Kate Domett (JCU) Dr James Moloney (JCU)
Research collaboration	Dr Rachanie Thosarat (Fine Arts Department of Thailand) Chanakarn Hongthong
Stipend	Australian Postgraduate Award 2013-2015
Financial support	JCU GRS SEES/ SASS Grants Earthwatch Institute JCU CASE Completion Scheme
Data collection	Dr Rachanie Thosarat (Fine Arts Department of Thailand) Chanakarn Hongthong
Thesis formatting & editing	Dr Caitlin Evans Dr Fay Stenhouse John Stenhouse

Keywords

Agricultural, Animal, Archaeology, Ecosystems, Ban Non Wat, Ban Salao, Bone, Bronze Age, Domestic, Faunal Remains, Fishing, Hunting, Husbandry, Iron Age, Khorat Plateau, Neolithic, Nong Hua Raet, Northeast Thailand, Phon Songkhram, Seasonality, Social Change, Southeast Asia, Subsistence, Upper Mun River Valley, Zooarchaeological

Abstract

Recent research has made considerable progress towards our understanding of the origins of agriculture and the domestication of animals in prehistoric Southeast Asia. This thesis will contribute to this knowledge by investigating the faunal assemblage from archaeological sites in the Upper Mun River Valley, northeast Thailand. The major goal of this research is to address the hypothesis:

Prehistoric communities in the Upper Mun River Valley became more reliant on domestic animals as part of their subsistence strategies over time, from the Neolithic to the Iron Age

To address this hypothesis 22283 vertebrate animal remains from the prehistoric sites of Ban Non Wat, Ban Salao, and Nong Hua Raet were identified and analysed into 57 taxonomic groups. From this analysis, the subsistence strategies in these early communities were determined. Whether these strategies changed throughout time, due to social changes, was investigated. The zooarchaeological records from the three sites were compared to modern comparative studies from the Hmong and Lao-Isan cultures of Southeast Asia.

The results show that the subsistence role of domestic animals in the Upper Mun River Valley changed from the Neolithic to the Iron Age. At Ban Non Wat, a site that encompasses a time span of 1650 BC to 500 AD, the volume (m^3) of pig and bovid remains increased in the Bronze Age contexts, with bovid remains increasing again in Iron Age contexts. This illustrates the increasing importance of animal husbandry at this site. Wild resources such as deer, fish, and turtle/ tortoise remains were also identified in lower volumes in Iron Age contexts in comparison to Bronze Age and Neolithic at Ban Non Wat. At Ban Salao, an Iron Age site (500 BC to 500 AD), bovid remains made up the majority of the assemblage, with pig second highest. Only a small number of deer, fish, and turtle remains were identified. Likewise, at the Iron Age site of Nong Hua Raet (500 BC to 500 AD), bovid remains were found more often than pig remains and other animals, such as deer, fish, and turtle. The age at death estimates for pig, and the frequency of skeletal elements at Ban Salao and Nong Hua Raet, indicates that pigs may have been raised or butchered offsite. The lack of fish species related to rice agriculture, and low numbers of rats and mice, suggests that Ban Salao and Nong Hua Raet were not intensive rice farming sites. It is argued that these sites were seasonally occupied. If the Iron Age results are analysed as a community of sites, it demonstrates clustered groups specialising in one or two resources, with linear communities sharing resources.

These findings demonstrate how the subsistence role of animals in early agricultural communities in the Upper Mun River Valley changed over time, with communities becoming more reliant on domestic animals from the Neolithic to the Iron Age. However, hunting and fishing remained an important part of subsistence strategies throughout all time periods at Ban Non Wat. The increased reliance on domestic animals confirms a socio-cultural change in subsistence towards the use of domestic animals as a food source, and provides evidence of an agricultural intensification of seasonal rice farming. The comparative studies from the Hmong and Lao-Isan cultures has led to the conclusion that the seasonal nature of intensive Iron Age agricultural may have had an influence on the season wild animals were hunted.

The results of this thesis are inconclusive as to which current model of social change in Southeast Asia the data supports. This may relate to the overlap within the structure of the models themselves, or suggest that no model entirely encompasses social change that occurred in the prehistoric communities of the Upper Mun River Valley. This research contributes significantly to our understanding of changes to subsistence resources in agricultural communities of Upper Mun River Valley and the wider Southeast Asian region.

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List of Abbreviations

AMS	Accelerator Mass Spectrometry
BNW	Ban Non Wat
BSL	Ban Salao
CDS	Crown development stage
D	Depth
Da	Depth of anterior cusps
Dist. W	Distal end width
Dm	Depth of middle cusps
Dp	Depth of posterior cusps
dp_4	Lower deciduous premolar 4
F	Feature
GS	General spit
I_1	Lower incisor 1
I^1	Upper incisor1
L	Length
M_1	Lower permanent molar 1
M_1-M_3	Lower molar row
M^1-M^3	Upper molar row
M_2	Lower permanent molar 2
M_3	Lower permanent molar 3
Max. D	Maximum depth
Max. W	Maximum width
Min. W	Minimum width
MNI	Minimum Number of Individuals
NHR	Nong Hua Raet
NISP	Number of Individual Specimens
P_4	Lower permanent premolar molar 4
Prox. W	Proximal end width
TWS	Tooth wear stage

Chapter 1: Introduction

Over the last five decades, substantial progress has been made in our understanding of the domestication of animals, and the introduction of agriculture into prehistoric Southeast Asia. This thesis contributes to this knowledge by examining vertebrate faunal remains from the prehistoric archaeological sites of Ban Non Wat (BNW), Ban Salao (BSL), and Nong Hua Raet (NHR), located in the Upper Mun River Valley, northeast Thailand. The major goal of this research is to investigate a hypothesised shift in subsistence strategy from wild to domestic animals, from the Neolithic to the Iron Age period. A further goal is to test if this shift in subsistence strategies in early communities was associated with wider social complexity changes occurring across Southeast Asia during prehistory.

This thesis is part of a larger collaborative project in northeast Thailand entitled *Society & Environment before Angkor*, which is the most recent chapter in a long history of archaeological research in the Upper Mun River Valley. In 1995, under the project title *The Origins of the Civilization of Angkor*, the current era of archaeological research started in the region (Higham & Thosarat, 2004). From 1995 to 2007, *The Origins of the Civilization of Angkor* project excavated at the sites of Ban Lum Khao, Non Muang Kao, Noen U-Loke, and BNW (Higham & Kijngam, 2009; Higham & Thosarat, 2004; Higham et al., 2007). Over seven seasons, from 2002 to 2007, the project examined a large area of excavation approximately 27m by 32m, at the site of BNW (Cawte et al., 2009). The project noted that wild animals, such as deer, were found more often in Neolithic contexts than domestic animals (Kijngam, 2010). At the end of 2007 the *Society & Environment before Angkor* team started excavations at BNW. Under this new project more focus was placed on the investigation of a series of archaeological sites within close proximity to each other, all within in the sub-district of Phon Songkhram. Particular attention was paid to past communities, changing social structures, and their relationship with climate (Chang, 2009). Excavation continued at BNW and two other sites in the sub-district, BSL (2009) and NHR (2010). The vertebrate faunal remains excavated from 2007 to 2011 at multi-period BNW (1650 BC to 500 AD), and an additional two excavations at the Iron Age sites of BSL and NHR (500 BC to 500 AD), provided a more comprehensive faunal dataset with which to study subsistence strategies over time, and between sites located in different environmental zones. The findings can then be used to test previous conclusions regarding prehistoric subsistence strategies in the region.

Shoocongdej (1996) maintains that researchers of Thai prehistory must adopt a problem-oriented approach that establishes a link between our conceptual archaeological framework and cultural comparative studies. Such an approach is particularly relevant for northeast Thailand where contemporary hunting is still practiced seasonally, and is strongly linked to a tradition of seasonal agriculture. In this thesis I will examine and make reference to ethnographic accounts of subsistence strategies in the region, and their relevance to prehistoric communities, integrating a comparative cultural approach.

1.1 HYPOTHESIS

The main aim of this research is to address the hypothesis that:

Prehistoric communities in the Upper Mun River Valley became more reliant on domestic animals as part of their subsistence strategies over time, from the Neolithic to the Iron Age

1.2 OBJECTIVES

The three objectives of this research are:

- To identify and analyse vertebrate animal remains from prehistoric sites in the Upper Mun River Valley of northeast Thailand
- To integrate a comparative cultural study into the zooarchaeological analysis of animal remains, within these prehistoric communities, and the broader Southeast Asia region
- To examine subsistence strategies in early communities in the Upper Mun River Valley of northeast Thailand, reveal if these strategies changed

throughout time, and if and how these changes are related to social, environmental, and/or technological change

The first objective is to identify as many vertebrate animal remains to species level as possible. The identified animal remains, and the subsequent analyses, are the primary data for this thesis. The vertebrate animal remains in this thesis came from the excavations of archaeological sites BNW, BSL, and NHR, which are located in the Upper Mun River Valley, northeast Thailand.

The second objective is to integrate a comparative cultural study into the interpretation of results from this thesis. This involves comparisons to modern case studies and ethnographic literature, and also, to a lesser extent, personal knowledge of strategies of resource use in Southeast Asia from participating in a number of field seasons. The latter approach is often used in zooarchaeological studies in Southeast Asia when interpreting faunal data, often purposefully but sometimes unintentionally or without critical reflection. A more directed and critical approach is discussed and used here. The use of a comparative cultural approach in this thesis is employed to bring the data back to the social or ‘day-to-day’ context, relating results directly to the prehistoric communities of the Upper Mun River Valley. This can then be expanded to the broader Southeast Asian region.

The third objective is to use the primary data from the first objective to examine the role that animals played in subsistence strategies of early communities in the Upper Mun River Valley. Subsistence strategies include the acquirement and production of a broad range of plant and animal resources. This research focuses on the change from wild to domestic animals throughout time, and whether these were related to social changes. The term ‘social change’ here includes technical changes, such as the Bronze Age to Iron Age transition c. 400 BC in Southeast Asia, and/or intensification in rice agriculture, along with increases in socio-political scale or complexity (Higham, 1989; O’Reilly, 2008; White 1995).

1.3 SIGNIFICANCE AND SCOPE

This research contributes significantly to our understanding of subsistence strategies in agricultural societies of mainland Southeast Asia. The significance is fourfold:

- Address a gap in the understanding of subsistence strategies in agricultural societies during periods of major social and environmental change in northeast Thailand
- Investigate current models of social change in Southeast Asian archaeology
- Assist future analyses and interpretations of animal remains from archaeological sites in seasonal, tropical climate zones within Southeast Asia and further afield
- Provide insight into prehistoric, historic and current subsistence practices that could aid in environmental management and sustainability for the future

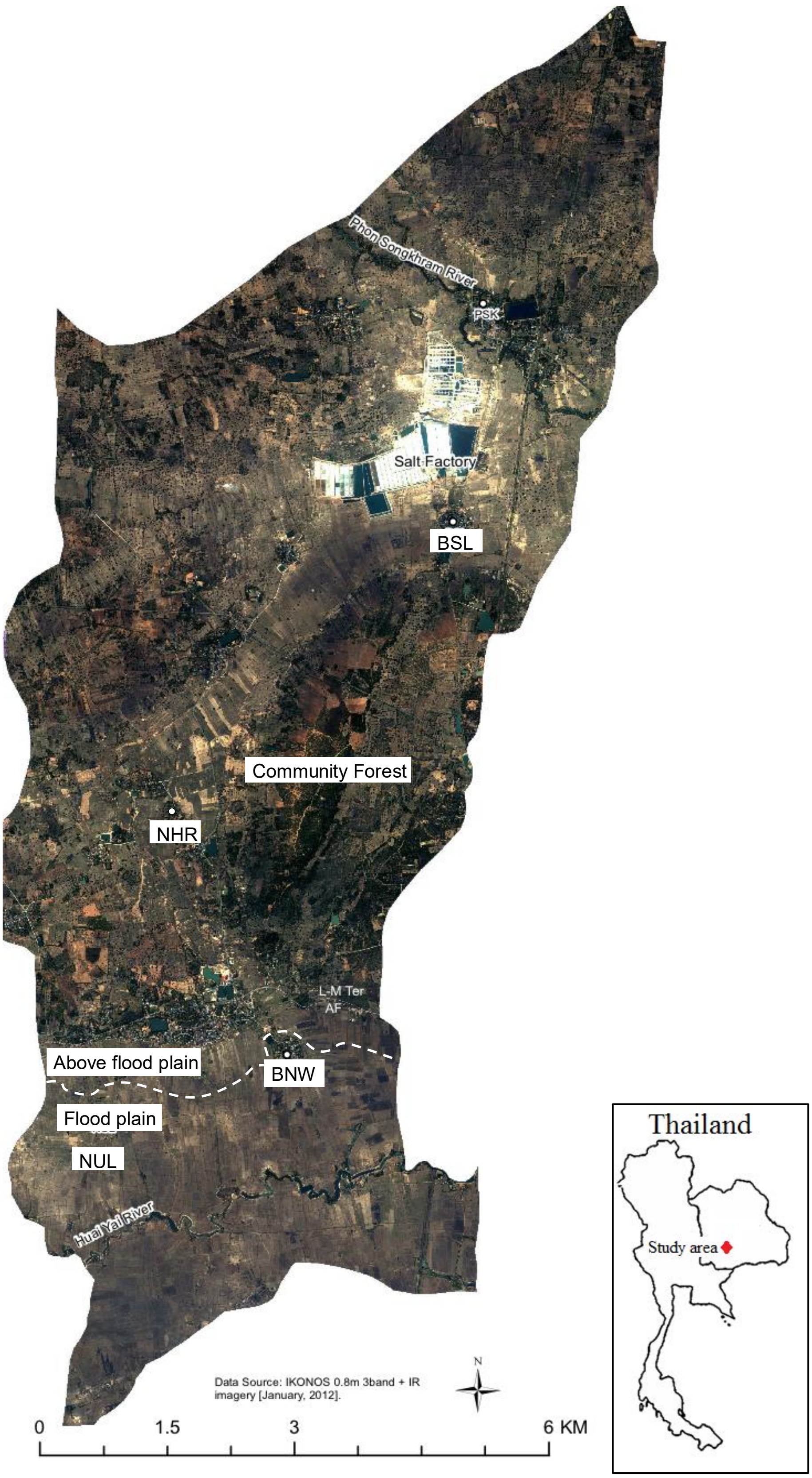
This research will also reveal new information regarding diet and nutrition, food processing, animal husbandry, hunting and fishing practices, belief systems, and the ecosystems inhabited by prehistoric people in the Upper Mun River Valley. By studying zooarchaeological assemblages, and comparing these with contemporary subsistence strategies within current agricultural communities, this research will contribute significantly to our understanding of subsistence resources in agricultural societies of Southeast Asia and the relationship between these resources and social change.

1.4 STUDY AREA

The three archaeological sites of BNW, BSL and NHR are located in the Upper Mun River Valley, northeast Thailand, in the present day sub-district of Phon Songkhram, Nakhon Ratchasima Province (Figure 1). Northeast Thailand is also known geologically as the Khorat Plateau. The Khorat Plateau lies between the Phetchabun, Dong Phaya Yen, and the Sankamphaeng Range Mountains in the west/southwest, and the Mekong River in the north and east. The site of BNW is situated on the present day flood plain, approximately one-and-a-half kilometres north of the Huai Yai River. The Huai Yai River is one of the tributaries of the Lam Prasat River, which flows northeast into the Mun River, and then flows eastward into the Mekong River System (O'Reilly, 2008).

The Upper Mun River Valley is a significant region in the understanding of socio-cultural development and the transmission of technology and/or ideas in Southeast Asia. In the first half of the second millennium BC Neolithic farmers, most likely originating from China, arrived in the valley (Higham & Rispoli, 2014). The introduction of rice and millet agriculture in the region corresponded with new ideas and technology, such as the domestication of animals, pottery, ground stone tools, spindle whorls, and village sized settlements (Bellwood, 2004, p. 21). In the late 11th century BC copper-base (Bronze Age) metallurgy was adopted and a widespread exchange network was developed. From approximately 500 BC iron technology (Iron Age) was adopted and trade networks grew. During this period prestige personal ornaments, made from gold, silver, agate, carnelian and glass, were placed with the dead, and evidence of ritual feasting can be found (Higham & Rispoli, 2014). Within these Iron Age communities population and sites grew in size and agriculture intensified, as society transitioned into a state-based structure, and moved into the historical period (Higham, 1989, pp. 153-155).

The site of NHR is located to the northwest of BNW and southwest of BSL. The site of BSL is located to the northeast of NHR and approximately two kilometres south of the Phon Songkhram River (Figure 1). The sites of BSL and NHR are two of many Iron Age mound sites on the Khorat plateau. The site of BNW is also a mound, although unlike BSL and NHR, BNW is surrounded by a ditch or rampart constructed during the Iron Age (500 BC to 500 AD), which is sometimes referred to as a moat (Boyd & McGrath, 2001). BNW also stands out from these other sites due to its long, continuous occupation from the Neolithic through to the Iron Age period (1800 BC to 500 AD). The sites of BSL and NHR are situated above the present day flood plain, whereas BNW sits in the present day flood plain (Figure 1).



Data Source: IKONOS 0.8m 3band + IR imagery [January, 2012].

Figure 1: The sub-district Phon Songkhram, northeast Thailand, showing the archaeological sites of Ban Non Wat (BNW), Ban Salao (BSL), Nong Hua Raet (NHR), and Noen U-Loke (NUL) (prepared by Evans, 2014)

1.4.1 Society & Environment before Angkor Project

The *Society & Environment before Angkor Project* is the most recent chapter in a long history of archaeological research on the Khorat Plateau, northeast Thailand (Gorman & Charoenwongsa, 1976; Solheim, 1968). In 1992, under the project title *The Origins of the civilization of Angkor,* Professor Charles Higham (Otago University, New Zealand), Dr. Rachanie Thosarat (Fine Arts Department of Thailand), and Dr. Amphan Kijngam (Fine Arts Department of Thailand), started archaeological research in the Upper Mun River Valley (Higham & Thosarat, 2004). From 2002 to 2007 *The Origins of the Civilization of Angkor* excavated a large area (approximately 27m by 32m) at the site of BNW (*Series 1 excavations*) (Cawte et al., 2009; Domett et al., 2016). The zooarchaeological findings from the *Series 1 excavations* is elaborated on in the *Chapter 2: Background, 2.2.5 Previous Zooarchaeological Studies at Ban Non Wat*.

At the end of 2007 a new research team, led by Dr Nigel Chang (Principal Advisor, James Cook University, Australia), Associate Professor Kate Domett (Co Advisor, James Cook University, Australia), Dr Amphan Kijngam (Fine Arts Department, Thailand), Dr Warrachai Wiriyaromp (Kasetsart University, Thailand) and Professor William Boyd (Southern Cross University, Australia), continued the excavations at Ban Non Wat (*Series 2 excavations*) (Chang, 2009). The new project was entitled *Society & Environment before Angkor: Ban Non Wat & the Upper Mun River Catchment in Prehistory*. Under this new project the focus shifted away from the broader northeast Thailand region to focus upon the sub-district of Phon Songkhram, with particular attention paid to past communities and their interactions within changing social structures and climate (Chang, 2009). Excavation continued at BNW, while two other sites in the sub-district, BSL (2009) and NHR (2010), were also excavated. The new project had a strong community-based approach. The project involved collaboration between the people of BNW and the Phon Songkhram Sub-district, the Fine Arts Department of Thailand, the Earthwatch Institute, and academics from both local and overseas universities. The project also integrated local community development projects such as the *Phon Songkhram Community Forest* project.

1.4.2 Phon Songkhram Community Forest Project

The *Phon Songkhram Community Forest* project runs alongside the *Society & Environment before Angkor* project. This project involves collaboration between Phon Songkhram sub-district government, environmental scientists from both James Cook University and Nakhon Ratchasima Rajaphut University (NRRU), and ecologists from James Cook University. The project investigates the ecology and modern utilisation of plant and animal resources in the Phon Songkhram, community forest in northeast Thailand. As part of the project Dr James Moloney (Co Advisor, James Cook University, Australia), along with Wassana Phanurak (NRRU, Thailand), and colleagues from the Suranaree University of Technology, have examined the biodiversity of the community forest and surrounding landscape. They discovered that the biodiversity within the community forest protected areas was in fact lower than that within some unprotected forested areas adjacent (Moloney et al., 2013). They also uncovered that the communities surrounding the protected areas intensively utilised the resources within, particularly with respect to firewood collection, hunting of birds and mammals, and mushroom/ herb collection (J. Moloney, personal communication, December 3, 2014).

1.5 THESIS OUTLINE

This thesis contains seven chapters. *Chapter 1: Introduction*, starts by stating the hypothesis, which is the core focus here. An overview of the main goals, their significance, and the location of this study is provided. An overview of past projects, and the project that this thesis is a part of, is also given. This chapter concludes with an outline of this thesis and a chapter summary. This is followed by *Chapter 2: Background* that provides a summary of the fauna of northeast Thailand. The present day subsistence strategies within the Hmong and Lao-Isan cultures of Southeast Asia are outlined. This chapter reviews previous research in the field of zooarchaeology in Southeast Asia, looking at pre-agricultural, coastal, and inland agricultural sites. *Chapter 3: Theoretical Approach* consists of two sections. The first section outlines the use of subsistence theories in zooarchaeological studies, such as middle-range theory and a comparative cultural approach. The second section explains the four main theories for social change in Southeast Asia and the zooarchaeological evidence that supports them.

Chapter 4: Methods outlines the methodology employed including the location of the excavation units, the excavation methodology, and screening methods used during and post excavation. The identification of bones from the archaeological sites and the measurements taken to aid in classification are also a part of this chapter. The age at death estimates used on pig mandibles from the archaeological sites are described here. This chapter explains the quantification techniques utilised in this thesis, including Minimum Number of Individuals (MNI) and Number of Individual Specimens (NISP). It concludes with a section discussing the ethical and legislative context for conducting zooarchaeaological research in the Kingdom of Thailand.

Chapter 5: Results is a detailed examination of the results, beginning with information on the state of preservation and fragmentation of the animal bones at the three sites (BNW, BSL, and NHR) analysed in this thesis. The findings are then separated into three sections by site. The NISP and MNI values for the three sites are given at the start of each section. Other results relevant to the sites, including identifying mouse and rat remains, the remains found in Iron Age bone midden features, dog burials, the distribution of NISP values through time, and the age at death estimates, can be found within these sections. The results chapter ends with a summary of the main findings from all three sites. The relevance of these findings are discussed in *Chapter 6: Discussion*. This chapter starts with a description of the differences in subsistence strategies between the three sites. This section discusses the management of freshwater resources and the use of traps in rice fields. The differences in zooarchaeological data from the Upper Mun River Valley at a site or community level is explored. The next section looks at evidence of seasonal or ritual feasting events at the three sites. The changes to subsistence strategies over time is discussed in more detail, with the aim to address the hypothesis: *Prehistoric communities in the Upper Mun River Valley became more reliant on domestic animals as part of their subsistence strategies over time, from the Neolithic to the Iron Age*. This is followed by a section focused on changes in the zooarchaeological record and how they relate to social changes in Southeast Asia. The last section presents the summary and future directions for the study of zooarchaeology in the Upper Mun River Valley. To finish, *Chapter 7: Conclusions* summarises the major findings of this research, and explains how the hypothesis and objectives from *Chapter 1: Introduction* are addressed throughout the course of this thesis.

Chapter 2: Background

This chapter starts with a summary of the fauna of mainland Southeast Asia, more specifically focusing on the native fauna of northeast Thailand. This provides a biogeographical setting of the animal species that could have been a part of present-day or past subsistence strategies within the region. This is followed by a comparative cultural study of present-day subsistence strategies practiced in two cultural groups in Southeast Asia; the Hmong and Lao-Isan. This outlines some of the current subsistence strategies used within the socio-environmental contexts of Southeast Asia. The comparative cultural study offers a variety of alternative anthropological perspectives on subsistence strategies within different agricultural communities, which are integrated into interpretations of the zooarchaeological record in this thesis. The zooarchaeological literature on faunal remains from previous excavations in Southeast Asia is presented. One of the main questions of this thesis is regarding changes to subsistence strategies over time. Pre-agricultural hunter-gatherer societies are reviewed briefly. However, post-agricultural farming societies are covered in more detail, as these sites are the main focus of this research. The zooarchaeological findings from previous excavations undertaken by the *The Origins of the civilization of Angkor* project in the Upper Mun River Valley, northeast Thailand, are also outlined in this chapter. This chapter ends with a summary of the implications of this literature for this thesis.

2.1 THE FAUNA OF NORTHEAST THAILAND

Northeast Thailand is situated in the tropical zone of mainland Southeast Asia. Like many tropical zones in the world, mainland Southeast Asia has a rich and diverse collection of fauna. The terrestrial fauna is described as Eurasian, with placental mammals such as Asian elephant, rhino, bear, tiger, deer, and wild cattle among the fauna found (Bellwood, 1992). The freshwater aquatic ecosystem is just as rich, with the Mekong River system being home to approximately 1200 species of fish (Rainboth, 1996). The area also contains a high diversity of freshwater turtles and tortoises (Stuart & Platt, 2004). Due to the extensive range of animal species found in northeast Thailand, only a small number of the species are expanded upon in this chapter, including those most commonly identified in zooarchaeological assemblages in northeast Thailand.

There are eight species of deer that are indigenous to Thailand; *Tragulus kanchil*, *Tragulus nigricans*, *Muntiacus feae*, *Muntiacus muntjak*, *Axis porcinus*, *Rucervus eldii*, *Rucervus schomburgki*, and *Rusa unicolor* (Francis, 2008, pp. 128-133). The modern and historical distributions of the two species of mouse deer, *T. kanchil* and *T. nigricans*, excludes the Upper Mun River Valley (Timmins and Duckworth, 2015; Widmann, 2015). The *Muntiacus feae* modern and historical distributions also exclude northeast Thailand (Francis, 2008, p. 128). The latter five species of deer had, or are thought to have had, their modern and historical geographical distribution across the Upper Mun River Valley, northeast Thailand (Francis, 2008; Kijngam, 2010). Out of the five species the smallest is the *Muntiacus muntjak* species known as the barking deer or red muntjac (Figure 2). The slightly larger *Axis porcinus*, known as the hog deer, is now extinct within Thailand but previously inhabited the northeast of the country (Figure 3). Hog deer was previously abundant in the Chao Phraya Basin, central Thailand during the early 20th century. However, the species became extinct by the mid-1960s (Humphrey & Bain, 1990). The larger *Rucervus eldii* species (known commonly as Eld's deer) inhabits lowland floodplains and feeds mainly on grasses (Figure 4) (Francis, 2008). The second largest deer species is *Rucervus schomburgki,* known commonly as Schomburgk's deer (Figure 5). The Schomburgk's deer is now extinct, with the last known wild animals believed to have died out in 1932, and the last captive individual in 1938 (Lekagul & McNeely, 1977). The historical biogeographical range of the Schomburgk's deer is unclear. Before its extinction in the wild, it was known to have inhabited the central plain of Thailand. It is unknown whether the Schomburgk's deer would have once populated the Mun River Valley. To date no antlers from the Schomburgk's deer have been discovered in any archaeological excavations in northeast Thailand. However, given that the Schomburgk’s deer once was adapted to the riverine plains of the Chao Phraya River basin, it could have populated the similar riverine plains of the Mun River Valley in prehistory (Kijngam, 2010). The largest deer species in Thailand is *Rusa unicolor,* known commonly as Sambar deer (Figure 6).

Figure 2: A male barking deer, *Muntiacus muntjak* at Khao Yai national park, Nakhon Ratchasima, northeast Thailand

Figure 3: A male hog deer, *Axis porcinus* at the Korat Zoo, Nakhon Ratchasima, northeast Thailand

Figure 4: A male and two female Eld's deer, *Rucervus eldii* at Korat Zoo, Nakhon Ratchasima, northeast Thailand (Kantorovich, 2016)

Figure 5: A male Schomburgk's deer, *Rucervus schomburgki* at the West Berlin Zoo (Schlawe, 1911)

Figure 6: A female Sambar deer, *Rusa unicolor* at Khao Yai national park, Nakhon Ratchasima, northeast Thailand

Three species of wild cattle and one species of water buffalo are known to have historically inhabited northeast Thailand; *Bos gaurus*, *Bos javanicus*, *Bos sauveli*, and *Bubalus arnee*. The *Bos gaurus,* known commonly as the gaur, is the largest species of wild cattle (Figure 7). In 1994 the Royal Thai Forest Department estimated at a total of 927 gaur individuals remained in the wild in Thailand (Srikosamatara & Suteethorn, 1995). *Bos javanicus*, known commonly as the banteng, is smaller and less muscular than the gaur (Figure 8). Similar to the gaur, in 1994 it was estimated that only 1840 banteng remained in the wild in Thailand (Srikosamatara & Suteethorn, 1995). *Bos sauveli*, known commonly as the kouprey, is on the critically endangered list, with less than 500 animals left in the wild (Timmins et al., 2016) (Figure 9). The wild water buffalo *Bubalus arnee*, is endangered, with some remnant populations in western Thailand and eastern Cambodia (Hedges et al., 2008) (Figure 10). Wild water buffalo habitat is grassland associated with alluvial flood plains (Francis, 2008, p. 325). The smaller domestic form *Bubalus bubalis*, however, is found in many environments within the region (Francis, 2008, p. 325).

Figure 7: A male gaur, *Bos gaurus* at the Korat Zoo, Nakhon Ratchasima, northeast Thailand (image by Chang, 2015)

Figure 8: A female banteng, *Bos javanicus* at the Korat Zoo, Nakhon Ratchasima, northeast Thailand (Kantorovich, 2016)

Figure 9: A male kouprey, *Bos sauveli* at the Vincennes Zoo, Paris (Broihanne, 1937)

Figure 10: A female and calf wild water buffalo, *Bubalus arnee* at Lunugamvehera National Park, Sri Lanka (Mammalwatcher, 2013)

The serow and goral are other members of the Bovidae family, which are goat-like ungulates, found in the hill and mountain regions of Thailand. There are three species of the *Capricornis* genera; the southern serow *Capricornis sumatraensis*, the Chinese serow *Capricornis milneedwardsii*, and the red serow *Capricornis rubidus*. Only the Chinese serow is found near northeast Thailand in the surrounding mountain ranges, sometimes entering lowland forest, though it does not enter cleared agricultural land (Francis, 2008, p. 326) (Figure 11). There are two species from the *Naemorhedus* genera; the Chinese goral *Naemorhedus griseus* and the red goral *Naemorhedus baileyi*. The Chinese goral is found in northern Thailand and Myanmar, whereas the red goral is found in northern Myanmar, southern China, and northeast India. Both species are found at altitudes above 1000m, on steep hilly terrain (Francis, 2008, p. 327).

Figure 11: A Chinses serow, *Capricornis milneedwardsii* at the Korat Zoo, Nakhon Ratchasima, northeast Thailand (image by Bannanurak, 2015)

The Eurasian wild pig or wild boar *Sus scrofa* (Figure 12) is common in many parts of the world and has one of the widest geographic distributions of all terrestrial mammals, in part due to human actions (Oliver & Leus, 2008). This is also, in part, due to the wide range of habitats they are found in; from semi-arid, to temperate, to tropical rainforests, including woodlands, grasslands, swamp and wetlands. Additionally, specimens often venture onto agricultural land to forage (Oliver & Leus, 2008). Groves (2007, pp. 22-23) lists seventeen subspecies of wild boar, although there is some evidence of hybridisation between groups. There is also hybridisation between wild boar and domestic pigs *Sus scrofa domesticus* in Southeast Asia, often making it hard to identify them to subspecies level. Studies have compared mitochondrial DNA phylogenies from archaeological specimens located in island Southeast Asia, with a modern pig baseline. They have discovered that wild boar *Sus scrofa* east of the Wallace Line are descended from introduced domestic pigs, likely originating from mainland Southeast Asia (Lucchini et al. 2005).

Recent geometric morphometric analyses have provided new insight into the domestication of pig in Southeast Asia and other parts of the world (Evin et al. 2017). Geometric morphometric has been used on second lower molar of *Sus scrofa* from the archaeological site of Zengpiyan in southern China, to test the claim that the site had the earliest domestication of pig c.8000 BC in the region (Cucchi et al.

2011). The analyses indicted the molars from Zengpiyan were from wild boars that were hunted at the site. This re-established the Yellow River region as one of the earliest centres of independent Chinese pig domestication.

Figure 12: A boar, *Sus scrofa* at Ban Non Wat, Nakhon Ratchasima, northeast Thailand

The Indochinese tiger *Panthera tigris corbetti* is a subspecies of tiger which was once common across Thailand, Vietnam, Cambodia, Laos, and Burma (Figure 13). However, today, like many big cat species around the world, the Indochinese tiger is endangered (Lynam & Nowell, 2011). Prior to over-hunting and habitat destruction, tigers would have been much more commonly found. Other big cats such as the leopard *Panthera pardus* and the clouded leopard *Neofelis nebulosa*, are also found in the region (Francis, 2008, p. 110).

Figure 13: A Tiger, *Panthera tigris corbetti* at the Korat Zoo, Nakhon Ratchasima, northeast Thailand (image by Chang, 2015)

The Muridae family of mice and rats is one of the largest rodent families in Southeast Asia. There are eight genera of rats and mice found in northeast Thailand; *Rattus*, *Bandicota*, *Berylmys*, *Niviventer*, *Leopoldamys*, *Maxomys*, *Mus*, and *Vandeleuria*. The *Rattus* genus once included several of the genera which are now recognised as separate, namely *Berylmys*, *Niviventer*, *Leopoldamys,* and *Maxomys* (Lunde & Son, 2001, p. 39). The *Rattus* genus now includes five species; *Rattus rattus*, *Rattus exulans*, *Rattus losea*, *Rattus norvegicus*, and *Rattus tanezumi* (Francis, 2008). *Rattus rattus*, the house rat, has an omnivorous diet and is mainly found in areas of human settlement as it feeds on house-hold waste (Francis, 2008, p. 351). The house rat is also a common pest species in agricultural areas, as it will feed on stored grain (Francis, 2008, p. 351). A similar pest species is *Rattus argentiventer,* the rice field rat. However, this species' habitat area is close to the coast line, including the Thai-Malay peninsula and much of island Southeast Asia. It is not found in inland areas such as northeast Thailand (Lunde & Son, 2001, p. 37; Pimsai et al., 2014). *Rattus exulans* (the pacific rat) is also found around house and grain stores, and sometimes enters rice fields (Francis, 2008, p. 352). *Rattus losea*, the lesser rice field rat, is located in grassland/ scrub habitats and can be a pest species in rice fields as it feeds on the plants (Francis, 2008, p. 354). *Rattus norvegicus*, the Norway rat, and *Rattus tanezumi,* the Asian house rat, are found around human settlements and are agricultural pests as they feeds on rice grains (Lunde & Son, 2001, p. 37-38). Norway rat is found more commonly in colder latitudes and it is thought to be native to Japan, Siberia, and northern China (Francis, 2008, p. 353). In tropical climates the Norway rat is found in habitats that have been highly modified by human activities (Musser & Carleton, 2005). There is no fossil record for the Norway rat species in Thailand (Pearch et al., 2013). The Norway rat most likely spread into northeast Thailand during the historic and modern period.

The *Bandicota* genus is represented by two species in northeast Thailand, *Bandicota indica*, the greater bandicoot rat, and *Bandicota savilei*, Savile's bandicoot rat. The greater bandicoot rat inhabits swampy areas including inundated rice fields, usually close to human activity (Francis, 2008, p. 355). The greater bandicoot rat also exploits rice fields as well as the edges of natural forests (Francis, 2008, p. 355). The white-toothed rat genus *Berylmys* has only one representative in northeast Thailand, *Berylmys berdmorei*, or Berdmore's rat. Berdmore's rat is found in forest and scrub, and sometimes enters agricultural areas close to forests (Francis, 2008, p. 356). There are seven species of the white bellied rat genus *Niviventer* in Southeast Asia. However, only one inhabits northeast Thailand, *Niviventer fulvescens*, the Indomalayan niviventer, which is found in forests and will also enter gardens (Francis, 2008, p. 361). The *Leopoldamys* genus also has just one representative in northeast Thailand, *Leopoldamys sabanus*, the long-tailed giant rat. The long-tailed giant rat is found in tall and secondary forests in lowland areas (Francis, 2008, p. 364). *Maxomys surifer*, the red spiny maxomys, also occurs in secondary as well as primary forests (Francis, 2008, p. 366). The red spiny maxomys, the long-tailed giant rat, the Indomalayan niviventer, and the Berdmore's rat are found in more natural forest habitats and are less associated with human occupation than the *Bandicota* and *Rattus* genera (Pimsai et al., 2014).

The mouse *Mus* genus has three representatives in northeast Thailand, *Mus musculus*, the house mouse, *Mus caroli*, the rice field mouse, and *Mus cervicolor*, the fawn-coloured mouse. The house mouse is associated with human occupation and resides primarily in built-up urban areas such as towns (Francis, 2008, p. 369). The rice field mouse and the fawn-coloured mouse occur in natural grassland, but also take advantage of rice fields (Francis, 2008, pp. 369-370). One species of the long-tailed climbing mouse *Vandeleuria* genus is found in northeast Thailand, *Vandeleuria oleracea*, the Asiatic long-tailed climbing mouse. The Asiatic long-tailed climbing mouse is found predominantly in dense vine tangles, tall cane and brush, as the species is arboreal (Francis, 2008, p. 372). Other small mammals from families such a Rhizomyinae (bamboo rat), Leporidae (hare and rabbit), Sciuridae (squirrel), and Soricidae (shrew) are also found throughout northeast Thailand.

The red junglefowl *Gallus gallus* is one of many species of bird native to Southeast Asia, and is also found in northeast Thailand (Figure 14). Red junglefowl has a large range and is found in many environments. The domestic subspecies of red junglefowl, the chicken *Gallus gallus domesticus,* is commonly found in villages in northeast Thailand and many parts of the world (Figure 15). Recent phylogenetic research has revealed multiple origins for the domestication of chicken, including

Thailand, Vietnam, Myanmar, India, and southern China (Kanginakudru et al., 2008; Liu, 2006). Northern China has also been suggested as the location of the origin of domesticated chicken (Xiang et al., 2014). However, Peters et al. (2015) argue against this claim, noting that the cooler climate during the mid-Holocene in the northern Chinese plains was unsuitable for the red junglefowl, the wild ancestor of domestic chickens. Much is still unknown about the geographic origins of domesticated fowl and it remains a topic of debate (see Eda et al., 2016; Eriksson et al., 2008; Kanginakudru et al., 2008; Liu, 2006; Peters et al., 2015; Xiang et al., 2014; Xiang et al., 2015).

Figure 14: A male red junglefowl *Gallus gallus* in west Bengal, India (Ash, 2014)

Figure 15: A male chicken *Gallus gallus domesticus*, at Ban Non Wat, Nakhon Ratchasima, northeast Thailand

Northeast Thailand also has a variety of freshwater turtles and tortoises. This includes members of the Geoemydidae family, such as *Batagur* sp. river terrapin, *Cuora* sp. box turtle, *Malayemys* sp. snail-eating turtle, *Mauremys* sp. pond turtle, and *Cyclemys* leaf turtles (Nutaphand, 1979; Stuart & Platt, 2004). Other families in the region include the Platysternidae big-headed turtle, the Testudinidae Tortoise, and the Trionychidae soft-shelled turtle (Nutaphand, 1979).

The Mekong River system, including its tributaries such as the Mun River and Chi River, support a rich diversity of freshwater fish. The number of species is continually increasing as new taxonomic studies and fish surveys are completed (Rainboth, 1996). For the purposes of this study, the most commonly identified freshwater fish recovered from zooarchaeological assemblages in northeast Thailand will be outlined. Carp (or minnow) is from the Cyprinidae family, which is represented by many genera and species in northeast Thailand. They can be found in large to small rivers and lakes and some members inhabit shallow rivers or streams (Rainboth, 1996, pp. 65-122). The bronze featherback *Notopterus notopterus*, in the Notopteridae family, is a fish that is found in freshwater lakes, canals, ponds, and floodplains (Rainboth, 1996, p. 56). The bronze featherback enters inundated floodplains including rice fields, to breed during the rainy season (Rainboth, 1996, p. 56). The Notopteridae family also contains the clown featherback *Chitala ornata* and the royal featherback *Chitala blanci*, which are found in large to medium sized rivers with flowing water (Rainboth, 1996, p. 55-56). The latter of the two is endemic to the Mekong River. The wallago catfish *Wallago* sp., of the Siluridae family, lives in larger streams and rivers. After recent osteological investigation by Roberts (2014), the wallago genus now includes just two species, *Wallago attu* and *Wallago maemohensis*. The other species that were previously included in this genus are now a part of the *Wallagonia* genus. There are currently three species of *Wallagonia* catfish, *Wallagonia leerii*, *Wallagonia maculates,* and *Wallagonia micropogon,* all of which are native to Southeast Asia (Roberts, 2014). *Wallagonia leerii,* the striped wallago or helicopter catfish, is found throughout mainland and island Southeast Asia (Roberts, 2014). *Wallagonia maculatus* is endemic to northern Borneo and *Wallagonia micropogon* is found in the Mekong River basin (Roberts, 2014). The butter catfish *Ompok bimaculatus*, also in the Siluridae family, is found in streams and rivers, and is known to use flood waters to move into new habitats (Rainboth, 1996, p. 149).

The naked catfish family Bagridae, is found in streams channels and moves into flooded forests to spawn (Voeun, 2006, p. 25). Common genera from the naked catfish family in northeast Thailand include the yellow catfish *Hemibagrus* and Tengra catfish *Mystus*. The yellow catfish *Hemibagrus nemurus* (Figure 16), will move into flooded rice fields during the wet season to spawn. The family Clariidae contains the walking catfish *Clarias* genus, which includes the walking catfish *Clarias batrachus* and broadhead catfish *Clarias microcephalus* (Figure 16). Members of the *Clarias* genus are known to live in floodplains and can survive in very low muddy ponds with little oxygen or food in the dryer months (Rainboth, 1996, pp. 162-163). The Asian swamp eel *Monopterus albus* (Figure 16), of the Synbranchidae family, is also found in the floodplains, predominantly in rice paddies. The Asian swamp eel survives the dryer months by burrowing into the mud to permanent water up to 1.5 meters below the surface (Rainboth, 1996, p. 177). The snakehead fish *Channa* genus in the family Channidae, are predominately found in rivers, lakes, and ponds (Rainboth, 1996, pp. 219-220). However, the black snakehead *Channa melasoma* and the snakehead murrel *Channa striata* (Figure 16), are found in swamps with sluggish or standing water (Rainboth, 1996, pp. 219-220). The former species is rare, and the latter of the two is very commonly found in rice fields in northeast Thailand (Lee, 1992). The Malayan leaf fish *Pristolepis fasciata*, from the Nandidae family, is found in sluggish or standing water, with a lot of aquatic vegetation and submerged branches or trees (Rainboth, 1996, p. 191). The Climbing perch *Anabas testudineus* (Figure 16), from the Anabantidae family, is found in ponds, lakes, and rivers in the dry season. During the wet season they move to flooded plains and rice fields to spawn (Voeun, 2006, p. 19). The gourami *Osphronemus* genus, from the family Osphronemidae, has two species in the region, the elephant ear gourami *Osphronemus exodon* and the giant gourami *Osphronemus gouramy*. The elephant ear gourami occurs in the middle Mekong and leaves the river to enter flooded forest during the wet season (Rainboth, 1996, p. 218). The giant gourami, and likewise the genus *Trichopodus* (also in the family Osphronemidae), is found in sluggish or standing water in lakes and ponds (Rainboth, 1996, p. 216, and 218).

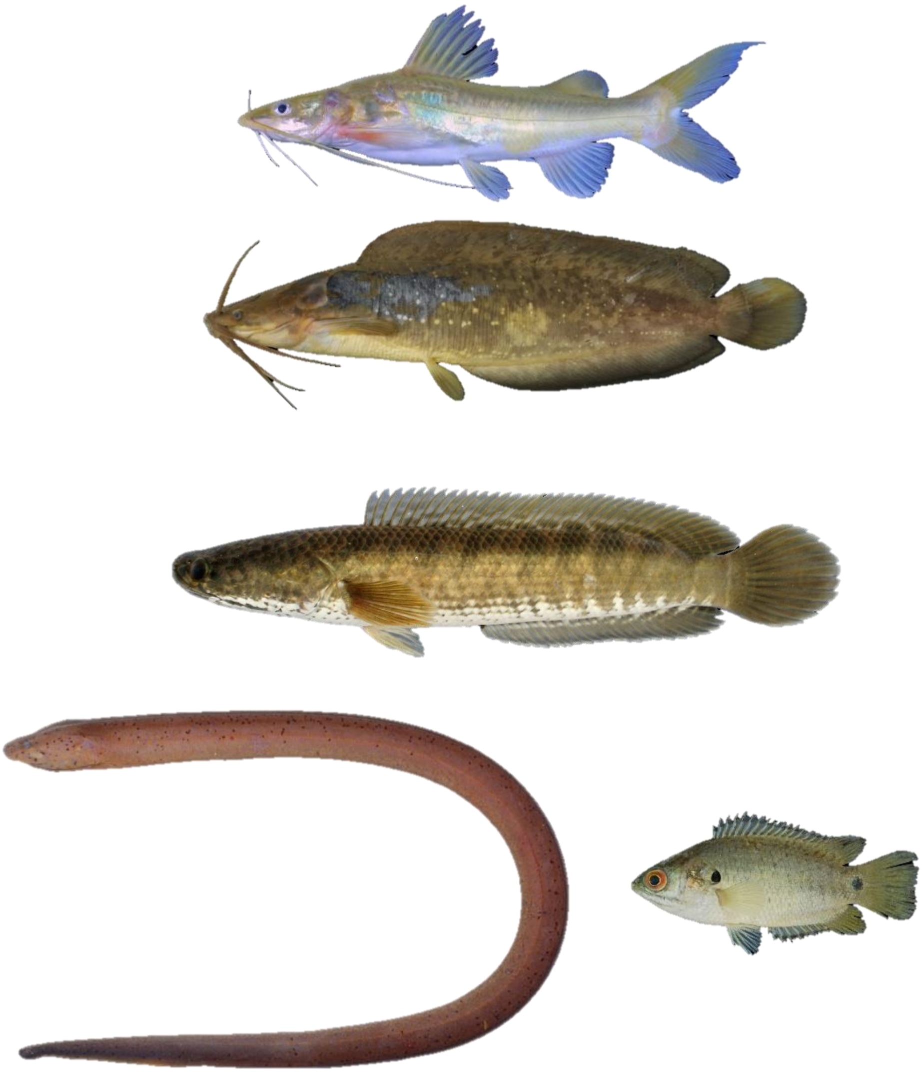


Figure 16: From the top; yellow catfish *Hemibagrus nemurus*, broadhead catfish *Clarias microcephalus*, snakehead murrel *Channa striata*, Asian swamp eel *Monopterus albus*, and climbing perch *Anabas testudineus* (After top to bottom: Praxaysombath, 2008; Tran, 2007; Adnan, 2008; Thach, 2008; Tran, 2007a)

2.2 ZOOARCHAEOLOGICAL ANALYSIS IN SOUTHEAST ASIA

Southeast Asia has had a long history of zooarchaeological research from the early 1900's up to the present day. The literature is split into two main study areas, pre-agricultural hunter gatherer societies and post-agricultural farming societies. The latter is the main focus of this thesis and will be covered in more detail in this chapter. The zooarchaeological studies on post-agricultural farming societies in the last five decades have centred upon the discourse of the origins of domestic animals in Southeast Asia. However, more recent studies from Vietnam on post-agricultural farming societies have started to investigate subsistence strategies and the proportion of wild and domestic animals utilised.

2.2.1 Pre-agricultural Societies

The earliest evidence of hunting strategies in Southeast Asia comes from inland rock-shelters and cave sites (c.30000 BC to c.2000 BC), where a number of excavations have uncovered a range of animal bones; including wild cattle, wild pig, deer, rhinoceros, wild water buffalo, and serow (Sarasin, 1933; Shoocongdej, 2006; Sørensen, 1979; Van Heekeren & Knuth, 1967). As well as animal bones, a number of stone tools have been found at these sites. However, Van Heekeren & Knuth 1967 noted that stone tools from Sai Yok rock-shelter, in Kanchanburi Province, Thailand (Figure 17), would have been unlikely to have been used for hunting due to their larger size, and it is more likely people hunted with wooden implements. It has also been suggested that many of the sites were occupied sporadically, rather than continually, by hunter-gatherer groups. A study by Shoocongdej (2000) on rock-shelters and cave hunter-gather sites in both inland and coastal regions in western Thailand, analysed the relationship between seasonal hunting and forager mobility organisation. Due to the location and nature of the cultural material found at the sites it was suggested that rock-shelters and caves were seasonally occupied and that the mobility pattern and social organisation of hunter-gatherer groups would have changed from the wet to the dry months.

Recent research by Conrad (2015) investigated zooarchaeological datasets from twenty-eight excavated hunter-gatherers sites in Thai-Malay Peninsula. The results show that shellfish were the most common taxon identified, followed by sambar deer, turtles and tortoises, barking deer, and wild boar. Conrad (2015) also notes that wild boar is more abundant in peninsular Malaysia faunal assemblages than in those from Thai sites. Of the aquatic resources, turtle and shellfish appear most frequently in the assemblage. These animals are slow moving fauna and thus would have been gathered rather than hunted. Conrad (2015) concludes by remarking that future research must explore the relationship in the consumption of slow moving fauna and the onset of agriculture and domestic animals in prehistoric societies in Southeast Asia. These types of questions are crucial to our understanding of the role that easily acquired resources played in the movement to a sedentary lifestyle.

Figure 17: Location of archaeological sites mentioned in this chapter (1 Sai Yok, 2 Nong Nor, 3 Khok Phanom Di, 4 Man Bac, 5 Samrong Sen, 6 An Son, 7 Ban Chiang, 8 Non Chai, 9 Ban Na Di, 10 Non Nok Tha, 11 Phum Snay, 12 Ban Lum Khao, 13 Noen U-loke, 14 Ban Non Wat, and, 15 Non Ban Jak)

2.2.2 Coastal Societies

The site of Nong Nor is located on the present day flood plain of the Bang Pakong River in Chonburi Province, central Thailand (Figure 17) (Higham & Thosarat, 1998). Higham and Thosarat (1998) discovered two phases of occupation at Nong Nor. The first was a short period of no longer than a few months, by a hunter-gatherer group at approximately 2450 BC. The second phase comprised a Bronze Age cemetery dating from 1100 BC to 700 BC. The first phase contained a shell midden of over six million shellfish, with the vast majority identified as one species; *Meretrix lusoria*, a marine cockle (Mason, 1998, p. 194). Mixed within the shell midden were other marine species, including the bones of shark and dolphin. Higham and Thosarat (2012, p. 49) argue that the bones of shark and dolphin at Nong Nor demonstrate that people went out to sea on fishing or hunting expeditions. Though Nong Nor was dominated by marine fauna, terrestrial species were also identified in low numbers within the shell midden context. Terrestrial species represented included deer, wild cattle, and wild water buffalo (Higham & Thosarat, 2012, p. 49; Higham et al., 1998). No dog bones were identified in the early phases of occupation at this site (Higham et al., 1998, p. 122). O'Reilly (1998a) suggested that the low number of torso bone elements of terrestrial mammals indicated that animals were likely butchered off site, and that the disarticulated limbs were returned onsite for consumption and secondary use. The secondary use of the bone material was in the manufacturing of fishhooks, awls, and other bones tools, which were also found at the site (O'Reilly, 1998a). The presence of fishhooks demonstrates that line fishing was a part of the subsistence strategy for the early inhabitants of Nong Nor.

The second Bronze Age phase of occupation at Nong Nor only identified fauna within graves at the site. Therefore, did not contain direct evidence of every day subsistence. This, however, provided an insight into mortuary feasting at the site. The most common offering found in the graves was dog skulls, which were placed just above the head. Pig feet (trotters) were also found within burial contexts (Higham, 1998, p. 315-16). One of the many pottery vessels found alongside burials contained the remains of a chicken (Higham, 1998, p. 316), and another burial contained the distal end of a *bos* sp. metatarsal (Higham, 1998, p. 315). Higham and Thosarat (2012, pp. 160-161) maintain that the Bronze Age people at Nong Nor would have cultivated rice and maintained herds of cattle and pigs, which were used in mortuary rituals.

The site of Khok Phanom Di is situated only 14 km to the North of Nong Nor in Chonburi Province, central Thailand (Figure 17) (O'Reilly, 1998, p. 94). Khok Phanom Di is one of the richest examples, in terms of burial wealth, of any pre-Bronze Age site ever excavated in Southeast Asia. Khok Phanom Di was first excavated by archaeologists from Silpakon University, Chachoengsao Teachers College, and the Fine Arts Department of Thailand (Noksakul, 1981; Pisnupong, 1984; Suchitta, 1980; Suchitta & Noksakul, 1979). In 1985 a large excavation measuring 10 by 10 metres was undertaken at Khok Phanom Di (Higham & Bannanurag, 1991). The large excavation established that Khok Phanom Di was occupied from c.2000 BC to 1500 BC (Higham, 2014). To date this is one of the most extensive zooarchaeological studies done in Thailand. The site contained both terrestrial, freshwater, estuarine, and marine fauna (Grant & Higham, 1991; Kijngam, 1991; West, 1991). Higham and Thosarat (2012, p. 57) argue that no domestic animals were kept at Khok Phanom Di, and the remains of pig and cattle recovered at the site were hunted from the wild. From visual inspection of two mandibles, and from measurements taken from the upper and lower molars, emerged the idea that pigs from Khok Phanom Di were of wild origin (Grant & Higham, 1991, p. 180). However, due to the fact that wild Thai pigs were often interbred with domestic pigs it is very difficult to distinguish between the two (Grant & Higham, 1991, p. 180).

The faunal assemblage at Khok Phanom Di was examined by layer and by feature, and also through time stratigraphically by dividing the layers of the site into three broad zones, A, B, and C (Grant & Higham, 1991, p. 188; West, 1991, p. 193). West (1991, p. 193) explains the three zones: A, B, and C. Zone A, the lower layers, is the initial occupation of the site. Zone A is dominated by shell and ash lenses that contain pottery, which were associated with mortuary rituals. Zone B, the middle layers, was a period of increases in burial practice and a reduction in the number of lenses and shell middens at the site. Zone C, the upper layers, was most likely deposited after site abandonment as the sea level had fallen and the river had moved away from the site. The Minimum Number of Individuals (MNI) were presented for each zone. The findings from Grant and Higham (1991) show the MNI for all species of deer remains became greater over time, transitioning from zone B to zone C. Dog bones were not found in the lower layers at the sites. Both dog and pig remains increased over time, although pigs were present throughout all layers in relatively high amounts. Cattle and water buffalo were absent in the lower layers in zone A and once again saw an increase from zone B to C. Two genera of old world monkeys, the macaque *Macaca* sp. and the leaf monkey *Presbytis* sp., were also identified at Khok Phanom Di (Grant & Higham, 1991, p. 168). The presence of non-human primates in faunal assemblages from archaeological sites in mainland Southeast Asia is rare. The macaque was found in greater numbers than the leaf monkey at the site, although, both increased over time from zone A to C (Grant & Higham, 1991, p. 169). The number of old world monkeys suggests that these primates were a substantial part of the subsistence strategies employed by the people of Khok Phanom Di. Grant and Higham (1991, p. 169) have proposed that the primates could have been caught in traps, hunted with a bow and arrow, or hunted with blow guns which is a method used by people living in the forests of Malaysia today.

All mammal fauna at the site of Khok Phanom Di increased over time, from the initial occupation of the site to its abandonment. The marine fauna, which was predominately marine shellfish, was more commonly found in zone A, the initial occupation of the site, and decreased in zone B and again in zone C (Grant & Higham, 1991, p. 190). This is explained by an environmental change, which caused the coast line to retreat, transforming mangroves into a freshwater swamp. This provided the perfect habitat for deer, pig, and water buffalo (Grant & Higham, 1991, p. 188).

Rats comprised more than half of all the microfauna identified at Khok Phanom Di, which included small mammals, Amphibians, Reptilia, and Aves (West, 1991, p. 193). West (1991) highlighted the importance of identifying the rat remains to genus or species level, as they are key environmental indicators. Zooarchaeological research from around the world has also established that both rats and mice are excellent indicators of not only environment but also human population density (O’Connor, 2008, p. 157). At Khok Phanom Di, West (1991, p. 196) measured black rat *Rattus rattus* skulls and mandibles from all three stratigraphic zones, discussed earlier. The results of the skulls measured shows that most of the outlying measurements are from zone C, the latest phases of occupation at the site. West (1991, p. 196) suggests that this may represent a transition in the range of sizes of rats that are hunted during the latest occupational layers. However, given the range of mandibular measurements in zone C, it is likely that the measurements are from other species of *Rattus* within Thailand, such as *Rattus exulans*, *Rattus losea*, *Rattus norvegicus*, and *Rattus tanezumi* (Musser & Newcomb, 1985). Some of the outermost measurements may also come from other genera of Muridae family (Lunde & Son, 2001, pp. 67-80). West (1991, p. 196) highlights that the measurements of the *Rattus rattus* skulls and mandibles at Khok Phanom Di formed the initial stage of analysis, and additional analysis with modern specimens is needed in future comparative studies.

Both the sites of Nong Nor and Khok Phanom Di were dominated by subsistence strategies based around marine shellfish. Inhabitants at both these sites would have travelled out to sea to fish using lines and fishhooks (Higham & Thosarat, 2012, p. 57). However, net weights and bone harpoons found at Khok Phanom Di, were absent in the artefact assemblage at Nong Nor (O'Reilly, 1998a). It is unclear why these artefacts were not present at Nong Nor. O'Reilly (1998a) suggests that the technology of net fishing was not utilised due to environmental conditions at Khok Phanom Di, or that the people at Nong Nor were unfamiliar with these fishing techniques. Additionally, fragments of rice were found at early phases at Khok Phanom Di but not recovered at Nong Nor until the Bronze Age phase. However, Higham and Thosarat (2012, p. 57) maintain it is unlikely the rice would have been farmed in such a saline rich environment, and that early inland rice farming communities could have traded rice, along with other items such as stone, to the site. Dog remains were not found at Nong Nor up to the late third millennium BC, and were also not present at Khok Phanom Di until the later periods of occupation. Kijngam (2010, p. 191) argues that this may be a result of contact with rice farming communities.

At the Neolithic site of Man Bac (1800 to 1500 BC) in the Yen Mo district, northern Vietnam (Figure 17), remains of both domestic dog and pig were present (Matsumura & Oxenham, 2011, and Sawada et al., 2011). Pig was the dominant species identified at Man Bac. The age at death profile, based on tooth eruption and wear, displayed a higher proportion of juvenile and young-adult animals (Sawada et al., 2011). The young age at death estimate and the age distribution is an indication of a managed domestic population (Albarella et al., 2006; Hongo et al., 2007). As well as raising pigs, the inhabitants of Man Bac also hunted deer, bovines, and small mammals (Sawada et al., 2011). It was noted that the diversity of wild mammals at Man Bac was less than that of the preceding hunter gatherer sites in Vietnam, which suggests that hunting activities were supplementing meat produced from domestic animals, rather than providing a subsistence staple (Sawada et al. 2011). Fishing was also a substantial part of the subsistence strategies at Man Bac. Toizumi et al. (2011), identified the majority of fish bones were from marine habitats, including littoral zone, open sea, and estuarine. Artefacts recovered from the sites that could have been used for fishing are bone points, bone harpoons, and stone net weights. Toizumi et al. (2011) hypothesised that spear, hook and lines fishing techniques were utilised. Although, no hooks were found at the site, it is thought that the numerous bone points were used as a gorge, a type of hook made from thin pieces of bone with points at both ends.

2.2.3 Inland Agricultural Societies

From 3000 BC to 1500 BC agricultural settlements were established across Southeast Asia, with the earliest agricultural communities generally found in the north (Bellwood, 2004, p. 22). Both rice and millet have been identified at agricultural sites in Southeast Asia (Castillo, 2011). The first evidence of domesticated rice remains in Thailand date to 2000 BC to 1500 BC from the coastal site of Khok Phanom Di (Thompson, 1996). A long held view is that the earliest rice agriculture was brought to Thailand by Austric speaking people from the Yangzi Valley in China, where rice was first domesticated (Higham, 1996, p. 337). Although, the group of people that brought rice agriculture to Thailand remains a matter of debate (see Bellwood, 2007; Blench, 2005; Castillo & Fuller, 2010; Van Driem, 1998). Archaeobotanical work has shown that millet agriculture pre-dates rice at some sites in Southeast Asia (Castillo, 2011).

The archaeological evidence associated with the earliest agricultural communities includes carbonised rice and millet remains, domesticated animal remains, pottery, ground stone tools, personal ornaments, spindle whorls, and village sized settlements (Bellwood, 2004, p. 21). The domesticated animal remains include dogs, cat, pig, chicken, cattle, and water buffalo, not previously identified in the zooarchaeological record at hunter gather sites in Southeast Asia (Higham & Thosarat, 2012, p. 78). It is conceivable that some of the domesticated animals, such as pig, chicken, cattle, and water buffalo, may have been locally domesticated, as they are native to Southeast Asia. However, domestic dogs must have been introduced as they are not present in the hunter-gather archaeological record, and the nearest native wolf populations reside in China and India (Higham et al., 1980).

One of the earliest documented inland zooarchaeological studies in Southeast Asia was undertaken at the site of Samrong Sen, a Neolithic to Bronze Age occupation and burial site (Mansuy, 1902; Mansuy, 1923). Samrong Sen is located on the east bank of the Stueng Chinit River, Kampong Chhnang Province, Cambodia (Figure 17). Although the site had been previously examined by Noulet (1879), a systematic stratigraphical excavation was not conducted until Mansuy (1902). The 1902 excavation at Samrong Sen identified terrestrial taxa such as cattle, pig, deer, dog, cat, rhino, elephant, reptile, and bird. Aquatic taxa such as otter, crocodile, turtle and marine snail were also identified in the faunal assemblage. No fish bones were identified, possibly due to an absence of wet sieving, however, fish hooks and fishing net weights were described. These finds emphasise the importance of river fishing in the subsistence strategy of this river-side community. This also highlights the importance of systematic sampling and recovery procedures, such as sieving and wet sieving.

The Neolithic site of An Son in Duc Hoa District, Vietnam resides approximately 75 km from the sea (Figure 17) (Bellwood et al., 2011). The site of An Son is a burial and occupation mound surrounded by a midden of material discarded during the occupation of the site (Piper et al., 2014). Prior to the occupation of the site, An Son was most likely located close to the coastline during a period of high sea level in the mid Holocene, between 4000 BC and 3000 BC (Proske et al., 2010). Although, by the time the site was inhabited, from 2100 BC to 1050 BC, the sea had receded (Bellwood et al., 2011). There was no evidence of marine fauna found from the excavations at An Son, and the species of shellfish identified suggested an inland lower riverine or upper estuarine environment (Bellwood et al., 2011). Fish bones identified from wet sieving were from freshwater species. The most commonly identified fish included snakehead murrel, Asian swamp eel, and climbing perch (Piper et al., 2014). Fishhooks were also present in the artefact assemblage at An Son (Bellwood et al., 2011). The fishhooks found at An Son were more than likely used in hook and line river fishing. Hard shelled turtles were found in high numbers at the sites, suggesting that turtles were targeted, possibly in traps or dug out of their burrows on the sides of river banks (Piper et al., 2014). Pig and dog were the predominate mammal identified in the assemblage (Piper et al., 2014).

Piper et al. (2014) compares measurements of dog mandibles from the site of An Son with present day samples of wild dogs and examples from the Higham et al. (1980) study of Thai archaeological sites. The dog mandibles from An Son fall outside the range for wild dog species. Additionally, the lower M_3 and the paired cusps on M_1 are present in all the specimens, which is a morphological feature only present in the *Canis* genera (Piper et al., 2014). The presence of these morphological features rules out the mandibles from being the dhole *Cuon alpinus*, as it is from the *Cuon* genus. From the measurements and the morphological features Piper et al. (2014) conclude that the majority, and most likely all the canid bones from An Son, are from domestic dogs. The dog bones at An Son had visible cut marks, suggesting there was no special treatment in the way dog remains and other animal refuse was deposited at site, that is, there were no ‘dog burials’ (Piper et al., 2014).

The pig teeth measurements from An Son were found to be similar to that of the modern wild Eurasian pig, *Sus scrofa*, from China (Piper et al., 2009; Piper et al., 2014). However, the age at death estimates for pigs at An Son suggests the management of a domestic population, similar to those recorded at Man Bac, with the majority of animals being young (Hongo et al., 2007; Piper et al., 2014). The studies at An Son highlight the difficulty in distinguishing between wild and domestic pigs in mainland Southeast Asia, with two different lines of evidence pointing to two possible conclusions.

The problem of distinguishing between wild and domestic pigs in mainland Southeast Asia at sites such as Khok Phanom Di and An Son is largely due to interbreeding and possible hybridisation (Albarella et al., 2006; Grant & Higham, 1991, p. 180). Evin et al. (2015) addressed this issue with a study on morphological changes to the tooth shape, linked to the phenotypic variation that occurs during domestication. Evin et al.'s (2015) study was able to identify differences in wild, domestic, captive wild, and hybrid *Sus* population from geographic regions around the world. However, further investigation is needed to see if zooarchaeological samples from mainland Southeast Asia can be identified using this method.

A substantial amount of zooarchaeological research has come from excavations of open sites dating to the Neolithic, Bronze Age, and Iron Age (c.2000 BC to c.500 AD) on the foot hills and flood plains of northeast Thailand (Higham & Thosarat, 2012). Although these sites are from the agricultural period, they contain both domestic and a sizable amount of wild faunal remains. The subsistence strategies of the northeast Thailand agricultural sites have a larger emphasis on hunting, trapping, and fishing than the agricultural societies of Man Ban and An Son in Vietnam.

Most of the zooarchaeological studies form the northeast Thailand region have come from the excavations of large mound and/ or moated sites, which are a feature of the Mun, Chi, and Songkhram River valleys (Higham, 1989, p. 219). The Chi River lies north of the Mun River and the two rivers join before flowing east into the Mekong River, on the modern day border of Thailand and Laos (Figure 17). The Songkhram River is to the north of the Chi River and follows to the east to join the Mekong River (Figure 17). Zooarchaeological studies from the Mun, Chi, and Songkhram River valleys have focused on the origins of agriculture and the domestication of animals (Higham & Thosarat, 2012). The majority of the literature attempts to identify which animals have been domesticated, as opposed to wild varieties, using the characteristics of the bones, such as the length and robustness.

A significant amount of zooarchaeological research was completed in the 1970s and 1980s on sites in the Songkhram and Chi River systems (Gorman & Charoenwongsa, 1976; Higham, 1975; Higham & Kijngam, 1984; White, 1982). By far the most well-known of these sites is the world heritage listed site of Ban Chiang. Ban Chiang is located in the Upper Songkhram River Valley, Nong Han District, Udon Thani, northeast Thailand (Figure 17). The 1974-5 excavation of Ban Chiang claimed very early Bronze and Iron Age dates (Gorman & Charoenwongsa, 1976; White, 1986). AMS dates on rice inclusions in burial pottery put the initial date range to 2100 to 1700 BC (White, 2008). Fragments of bronze found in occupation contexts were dated to approximately 2000 BC (White & Hamilton, 2009). More recent data from animal bone collagen found that the initial Neolithic settlement took place approximately 1500 BC, and that the first bronze appears at 1000 BC (Higham et al., 2011). The dating and earliest metal technology in the region remains a major topic of debate (see Higham et al., 2011; Higham & Higham, 2009; White, 2008; White & Hamilton, 2009).

Higham and Kijngam (1979) demonstrate that the initial inhabits of Ban Chiang had a range of subsistence strategies, which included collecting freshwater shellfish, fishing, hunting of wild animals, and the keeping of domestic animals. Higham et al’s (1980) study used multivariate and morphological analyses of canid bones to determine that the domestic dog, *Canis familiaris,* was present at Ban Chiang and was possibly used for hunting purposes. Freshwater shell fish were abundant in the early layers of the site, after which they became rare. Higham and Kijngam (1979) argue that this is due to environmental and technological changes, stating the first inhabitants of the site would have occupied an environment with lake and sand swamps fed by permanent streams, and probably practiced swidden farming. The next phase saw the introduction of iron technology, which coincided with a reduction in standing water bodies. It is also suggested that during this phase wet rice cultivation was practiced. During this phase the presence of water buffalo bones increases, and the bones also show areas of stress probably due to ploughing.

Water buffalo was most likely used as a draft animal to plough fields and would have been a major factor in the intensification of wet rice agriculture. Ploughing fields with draft animals is more efficient at loosening soil than using digging sticks or hoes (Higham et al., 1981; Nanda & Warms, 2014, pp. 115-116). Ploughing coupled with irrigation exposes larger areas of land that can then be opened up and used more frequently (Higham, 2015; Nanda & Warms, 2014, p. 116). Archaeological excavations in the Upper Mun River Valley have uncovered a number of Iron ploughshares at sites such as BNW, Noen U-loke, and Non Ban Jak (Higham & Rispoli, 2014). A ploughshare is the blade used to cut through the earth during the act of ploughing, often pulled by draft animals (Nanda & Warms, 2014, pp. 115-116). The time period that domestic water buffalo start to be utilised as draft animals to plough fields is important in establishing the beginnings of intensive wet rice in Southeast Asia.

In order to establish what time domestic water buffalo appear in the zooarchaeological record it is necessary to identify them separately from wild water buffalo and other large bovids. In the Holocene wild water buffalo, *Bubalus arnee,* would have had a distribution across most of the tropical Asian zone (Patel & Meadow, 1998). The main difference between wild and domesticated water buffalo is the body size, as the wild buffalo are much larger than domestic examples (Patel & Meadow, 1998). However, some overlap is seen between large domestic male buffalo and wild female buffalo. Kijngam (1979) was able to distinguish between genera of buffalo (*Bubulus*) and cattle (*Bos*) on the basis of morphological differences for several bone elements at the site of Non Chai in the Chi River Valley, northeast Thailand. This method was further employed at the sites of Ban Na Di in the Pao River Valley (Higham, 1975), Nong Nor and Khok Phanom Di in central Thailand, and additional sites excavated by Higham in the Mun River Valley including the site of BNW (Kijngam, 2010, p. 190).

The site of Ban Na Di to the south of Ban Chiang was excavated in 1980 (Figure 17) (Higham & Thosarat, 2012, p. 112). The initial settlement of the site was in the Bronze Age, with the early layers of the site containing evidence of cast bronze artefacts found in Bronze Age graves (Higham & Kijngam, 1984). The earliest phase at the site was originally dated to 1400 BC (Higham & Kijngam, 1984) However, the charcoal samples used for radiocarbon dating came from questionable contexts, and the initial settlement more likely dates to between 700 BC and 400 BC (Higham & Thosarat, 2012, p. 112). The zooarchaeological record showed a range of subsistence strategies related to domestic cattle, pig, and dog remains (Higham & Kijngam, 1984). The remains of shellfish, turtles, and numerous freshwater fish remains were found throughout all layers (Higham & Kijngam, 1984). The people of Ban Na Di also hunted or trapped several varieties of deer including sambar, Eld's, hog, and barking deer (Higham & Kijngam, 1984). Similar subsistence strategies were identified at the site of Non Nok Tha to the southwest of Ban Chiang and Ban Na Di, excavated in 1966 and 1968 (Bayard, 1970; Bayard et al., 1982). The burials at Non Nok Tha contained dog, pig, and small deer. Domestic cattle bone was also found at the site (Higham & Thosarat, 2012, p. 123). Small fish vertebrae were found in several pots in burials at the site, likely indicating the use of fermented fish products (Bayard et al., 1982). A comparable complete pot containing fish bones was found at the site of Phum Snay in Cambodia (Voeun, 2008). Voeun (2008) suggests these remains were from preserved fish products, such as salted or fermented fish. Further evidence of fishing practices at Non Nok Tha included bone bipoints, which are speculated to be gorge hooks used for fishing (Bayard et al., 1982). The excavations at the sites of Ban Chiang, Non Chai, Ban Na Di, and Non Nok Tha have shown a range of subsistence strategies, including hunting, fishing, and gathering of wild animal resources. There was also evidence of the raising of domestic pig, cattle, dog, and rice cultivation.

2.2.4 Previous Zooarchaeological Studies in the Upper Mun River Valley

The site of Ban Lum Khao, just to the southeast of BNW, is one of the few non-moated sites excavated in the Upper Mun River Valley, northeast Thailand (Figure 17). The site was excavated as part of *The Origins of the civilization of Angkor* project (Higham & Thosarat, 2004). The initial occupation has been dated to the late Neolithic c.1100 BC (Higham, 2004, p. 5). No dates have as yet been obtained for the final phase of burials at Ban Lum Khao. This is due to a lack of suitable dating material (Higham, 2004, p. 5). However, the pottery found in the graves at Ban Lum Khao was comparable to those recovered in Iron Age graves at Noen U-Loke (Higham, 2004, p. 5). The pottery vessels would place the last phase of burial at Ban Lum Khao at the start of the Iron Age c.600 BC to 550 BC, (Higham, 2004, p. 5).

The majority of burials at Ban Lum Khao contained the remains of sub-adult pig (Higham, 2004a, pp. 160-161; Higham & Thosarat, 2012, p. 127). The remains from dog, deer, bird, frog, turtle or tortoise, rat, and other small mammals were also found in burial contexts (Higham, 2004a, p. 161). The zooarchaeological sample was small and it was dominated by pig, which were found throughout all contexts. Dog remains were also found in low quantities throughout all layers. Cattle were rare at the site, though water buffalo was common in the lower layers (Higham, 2004a, p. 159). Likewise deer was more common in the lower layers, with Eld's deer the most frequently identified deer species. Other species such as the larger sambar and the smaller barking deer were also present (Higham, 2004a, p. 159).

Freshwater fish was a significant part of the subsistence strategy at Ban Lum Khao. The most commonly represented species was the snakehead murrel, the climbing perch, and the walking catfish (Thosarat, 2004, p. 171). There were no fish-hooks, harpoons, or net weights recovered from Ban Lum Khao (Thosarat, 2004, p. 179). Thosarat (2004, p. 180), therefore, concluded that the most likely techniques used were bamboo traps or hand fishing. Fish were also found in burials as mortuary offerings, but only in the late Iron Age phase of the site (Thosarat, 2004, p. 173). This demonstrates that fish had both a subsistence and a ritual purpose. Evidence of this practice was also found at the Iron Age moated site of Noen U-Loke, to the west of BNW in the sub-district Phon Songkhram (Thosarat, 2007, p. 538) (Figure 1). Although complete fish skeletons were found in pottery vessels from mortuary contexts at Noen U-Loke, in contrast to Ban Lum Khao, very few fish bones were recovered from other contexts (Thosarat, 2007, p. 537). The lack of fish bones in the wet sieve sample is difficult to explain given the sites close proximity to water and the many shellfish recovered (Thosarat, 2007, p. 537). Thosarat (2007, p. 537) suggests that cooking or preparing methods could have been different at the site, or that the processing of fish was undertaken at other areas at Noen U-Loke that are yet to be excavated.

As well as the fish remains, the site of Noen U-Loke demonstrated further evidence of subsistence strategies dissimilar to those exhibited at Ban Lum Khao. The majority of fauna identified from the excavation were from domestic animals (McCaw, 2007, p. 513). The lower layers at the site were dominated by cattle and pig remains, with water buffalo noted in lesser amounts (McCaw, 2007, p. 513). The most common species of animal found in mortuary contexts at Noen U-Loke was pig (McCaw, 2007, p. 516). The majority of the pig was very young, with only five of the specimens being sub-adult or older (McCaw, 2007, p. 516). Chicken and dog remains were found in the later layers at the site, along with frog, small mammals, birds, and cat (McCaw, 2007, p. 513). Likewise rat remains became frequent in the upper layers of the site, which is possibly related to the storage of food (McCaw, 2007, p. 513). Deer was present in small numbers throughout the sequence (McCaw, 2007, p. 513). Eld's and sambar deer were found in the lower layers at the site, with Eld's deer increasing in layer four, and then decreasing to less than five per cent of the total MNI in the upper layers (McCaw, 2007, p. 513).

The different subsistence strategies from the predominantly Bronze Age site of Ban Lum Khao to the later Iron Age site of Noen U-Loke, show a change from wild to domestic animals resources. This supports the hypothesis in this thesis outlined in *Chapter 1: Introduction 1.1 Hypothesis* that people transitioned towards domestic subsistence strategies over time. However, this may be due to localised geographic factors, such as access to resources. Likewise, this could be due to a specialisation in resources targeted or domesticated at a site. Also, it has been suggested by McCaw (2007, p. 513) that during late Iron Age at Noen U-Loke an intense period of hunting left wild resources such as deer depleted. Additional zooarchaeological analysis of sites such as BNW, with its continuous occupation from the Neolithic through to the late Iron Age period, will help in answering these questions. Furthermore, the addition of other interrelated sites in close proximity to one other will assist in understanding how these sites operated as a bordered community.

2.2.5 Previous Zooarchaeological Studies at Ban Non Wat

From 2002 to 2007 *The Origins of the civilization of Angkor* excavated a large central square on the high point of the mound at BNW in the Upper Mun River Valley (*Series 1 excavations*), introduced in *Chapter 1: Introduction, 1.4.1 Society & Environment before Angkor project* in this thesis (Higham & Kijngam, 2009). A wide-ranging collection of domesticated and non-domesticated faunal remains were uncovered, from Neolithic, Bronze Age, and Iron Age contexts during the first series of excavations (Higham, 2012a; Iseppy, 2012; Kijngam, 2010; Thosarat, 2010; Thosarat, 2012; Thosarat, 2012a). There has been some evidence that points towards the initial occupation of the site by hunter gatherer groups, due to flexed burials in the lowest layers of the site (Higham, 2009a, p. 154). Flexed burials are usually associated with hunter-gatherer groups in Southeast Asia, such as an example found at the site of Nong Nor. However, a lack of other stratigraphic information has made it difficult to place the flexed burials in the stratigraphic sequence (Higham & Wiriyaromp, 2010 p. 6). The flexed burials at BNW contained freshwater bivalve shells, and one burial contained a skull of a pig (Higham & Wiriyaromp, 2010).

Due to the lack of faunal remains found associated with the flexed burials it is impossible to know the subsistence strategies of the earliest inhabitants at the sites of BNW. Higham and Thosarat (2012, p. 72) maintain that inland hunter-gatherer groups would have practised a broad-spectrum subsistence strategy targeting everything from crabs, shellfish, fish, small mammals, deer, and even large mammals, such as rhinoceros. The diverse population of wild animals available to the first inhabitants at BNW suggests that the environment must have been vastly different to the modern day cleared, agricultural setting. Studies by Boyd and McGrath (2001) and Kijngam (2010) suggest that the Neolithic environment was a mosaic of woodlands, forests and wetlands, with small agricultural plots around villages.

The Neolithic zooarchaeological record at BNW sees the arrival of domesticated animals into the faunal assemblage, including cattle, pig, and dog (Kijngam, 2010). Only a few bones from water buffalo were found in Neolithic contexts at BNW, and given their large size are more likely to have come from the hunting of wild water buffalo rather than domestic animals. Small amounts of chicken/ red junglefowl bones have also been identified, which Kijngam (2010, p. 196) suggested might be domestic in origin. Deer was a substantial part of the Neolithic subsistence strategy at BNW. The hunting of deer at BNW targeted medium size deer species, including Eld's deer and Schomburgk's deer. Sambar deer, hog deer and barking deer were also found in Neolithic contexts, although in much smaller numbers (Kijngam, 2010, p. 189). The Eld's deer and Schomburgk's deer NISP outnumber that of pig and cattle. However, the fish, turtle and tortoise remains were found in greater numbers than all terrestrial mammals (Kijngam, 2010, p. 189; Thosarat, 2010, p. 170). The early Neolithic phase of BNW also contained a large shell midden similar to those recovered from the early phases of sites such as Ban Chiang and the costal site of Khok Phanom Di (Thosarat, 2010). The most common fish found in the Neolithic contexts was the naked catfish (*Hemibagrus* sp. and *Mystus* sp.), followed by the walking catfish *Clarias* sp. and snakehead murrel *Channa striata*. The butter catfish *Ompok bimaculatus* and wallago catfish *wallago* sp. were also high in numbers in Neolithic contexts (Thosarat, 2010, p. 170).

A full zooarchaeological analysis has not yet been published for the Bronze Age and Iron Age contexts from the past excavations at BNW. Although some indication of the subsistence strategies can be found in the mortuary contexts, and Iron Age bone and pottery midden features which are published in full. The fish remains from features, and from two small excavation units (unit Y1-Y2 to the northeast of the mound and X1 to the south of the mound), were the only Bronze Age and Iron Age samples analysed (Thosarat, 2012; Thosarat, 2012a). The most frequently identified species from the Bronze Age were the walking catfish, the snakehead murrel, the yellow catfish/ tengra catfish, and the Asian swamp eel (Thosarat, 2012, p. 588). In the Iron Age contexts the walking catfish, the naked catfish, the butter catfish, and the climbing perch were the most common (Thosarat, 2012a, pp. 51-53).

Higham (2012a) and Iseppy (2012) have analysed the bones from Iron Age bone and pottery midden features. The features have been dated to the early Iron

Age. Along with animal bone, stone anvils and iron knives were also found (Higham, 2012, p. 13). The midden features were interpreted as butchery floors, as a product of increased ritual mortuary feasting in the Iron Age at BNW (Higham, 2012b; Iseppy, 2012). The midden features contained the remains of water buffalo, cattle, pig, dog, deer, turtle, frog, rat, and fish (Higham, 2012a, pp. 56-58). The majority of the remains in the midden features were bovid and pig. Out of the bovid remains there was an overwhelming proportion of water buffalo (Higham, 2012a p. 56). A whole dog skeleton was also recovered from the Iron Age layers at BNW and a second skeleton was found in a human burial context (Iseppy, 2012, p. 32). This shows that dogs in the Iron Age at BNW were utilised as more than just a food source. Unlike the site of An Son in Vietnam, where no special treatment of dog remains were found (Piper et al., 2014).

Without the entire Bronze and Iron Age zooarchaeological analysis from previous BNW excavations, it is hard to know to what extent the midden features are representative of the whole subsistence strategies at BNW. Are the activities related to these features an offshoot of overall subsistence strategies, or do they represent a change in overall strategy during this time period? It also hard to track how the subsistence activities change over time, as it is important to have the complete faunal record from all time periods to provide context, and in order for comparisons to be drawn.

2.3 CONTEMPORARY SUBSISTENCE STRATEGIES WITHIN SOUTHEAST ASIA

This comparative cultural study will examine the ecology, animal resources, seasonality, and technology of two present day cultural groups in Southeast Asia, the highland Hmong and the lowland Lao-Isan. The Hmong and Lao-Isan were chosen due to their dissimilar agricultural and socio-environmental settings; with Hmong swidden farming the highland regions of Southeast Asia, and the Lao-Isan practicing intensive paddy farming within the lowlands of northeast Thailand. By investigating two groups who operate in contrasting environmental settings and who utilise two such distinct agricultural techniques, a range of alternative anthropological perspectives can be developed, taking into account the impact of seasonal variation, agricultural cycles, and the variety of subsistence techniques. These perspectives will, ultimately, be used to construct models that can then be tested through the zooarchaeological record of prehistoric sites in northeast Thailand, and used in this study. This is in order to better understand prehistoric subsistence strategies in their past environmental contexts, and to expand on the interpretation of the results of this thesis.

2.3.1 Socio-environmental Context

Southeast Asia is part of the seasonal tropical monsoonal climate zone, where there is a summer wet season, with heavy rainfall from May/ June to October/ November, and a winter dry season, with moderate rainfall for the rest of the year (Pant et al., 2005). Due to the climate, present day agricultural practices in Southeast Asia revolve around these two seasons; with the wet season dedicated to planting rice, and the dryer months to harvesting. The seasonality of this agricultural system is also due to the highly intensified nature of modern agricultural practices. Modern commercial agricultural practices known commonly as cash crop cultivation began in the early 1950s and spread across Southeast Asia. Initially starting with rice in the lowland paddy areas and then expanding into the upland areas with crops such as cotton, tobacco, opium and sugarcane (Vityakon et al., 2004). Typical farming practices in Southeast Asia differ according to altitude; lowland areas are predominately used for rice paddy farming, the hillsides used for sugarcane, root vegetables and other less water tolerant crops, and the mountains mainly for swidden cultivation (Yamada et al., 2004). The variety of rice planted by highland swidden farmers, which is often referred to as dry-rice, is different to the rice planted in the more labour intensive lowland paddy system, known as wet-rice (Yamada et al., 2004).

Southeast Asia has a complex social landscape with a wide range of cultural groups inhabiting its lowlands, hillsides, and mountains. The altitude generally divides ethnicity within the region, with the Lao-Isan groups farming in the flooded plains and foothills, the Khamu groups farming the middle slopes, and the Hmong groups farming the upper mountain regions (Sodarak, 1999). Largely due to modern commercial agricultural practices there has been a substantial decline in forested areas that are utilised for hunting and gathering local resources (Somnasang et al., 1998). Despite the decline in forested areas many people from Southeast Asia still gather or hunt wild foods from the remaining forested areas and utilise what wild resources are available in the rice fields (Somnasang et al., 1998). Due to the agro-ecological setting and the natural biological resources available, subsistence strategies can vary considerably within localised areas.

2.3.2 Origins of the Hmong

The Hmong's original homeland is southern China, most likely originating around the basin of the Yellow River in present day Hunan Province, during and dating back to the end of the third millennium BC (Lee & Tapp, 2010). The first record of non-Han groups in southern China, found within Chinese historical texts, occurred in approximately the twenty-seventh century BC. These texts referred to groups named Miao (Geddes, 1976, p. 3). The name Miao encompasses the Hmong as well as other non-Han groups living in southern China. Despite several obscure references, the Miao were not frequently mentioned in historical records until the Yuan dynasty (1271 to 1368 AD) (Lee & Tapp, 2010). During the Qing dynasty (1644 to 1911 AD) the Han Chinese referred to the Miao as more than one group and split the group base roughly by the colour of the women's clothing; such as the Bai (white) Miao, Hei (Black) Miao, Qing (Green/Blue) Miao, Hong (Red) Miao, and Hua (Flowery) Miao (Lee & Tapp, 2010). These names are sometimes still used today as a general term of reference to a particular Hmong group (Geddes, 1976; Lee & Tapp, 2010).

From 1733 to 1873 a number of Miao rebellions broke out against Han Chinese rule. Following extensive fighting back and forth, many Hmong chose to flee and settle in Southeast Asia (Lee & Tapp, 2010). Today the Hmong live in many parts of the world, including parts of Southeast Asia, China, America, Europe, and Australia (Schein, 2004). The settlement of Hmong around the world means their way of life has been influenced by many cultures. This review will focus on the Hmong cultural groups in the mountains and foothills of Vietnam, north Thailand, and Laos. Although the Hmong populations from these regions have very different modern histories, the majority still maintain their traditional practices (Lee & Tapp, 2010).

2.3.3 Hmong Subsistence Strategies in the Upland Forests

Like many ethnic groups from the highlands of Southeast Asia the Hmong are primarily subsistence rice swidden farmers (Delang, 2002). A typical Hmong village is surrounded by forest, with cleared sections for planting rice for one or two seasons before the land is left fallow to regenerate (Delang, 2002). Animal husbandry is also a part of village life, with domestic animals including chickens, turkeys, ducks, pigs, buffalo, cattle, horses, and goats raised for food consumption, sale and for use in ceremonies (Sodarak, 1999). Buffalos and horses are also kept for work purposes, and dogs are kept by some households as watch dogs and sometimes for hunting (Sodarak, 1999).

The Hmong have maintained a strong focus on traditional subsistence hunting, fishing, and gathering of forest resources (Johnson et al., 2003; Johnson et al., 2004). The Hmong hunt animals for the majority of the year, however more hunting is practiced during dryer months from September to February, with the exception of frogs, which are collected at the start of the wet season in May and June when they are much easier to locate (Johnson et al., 2003). A wide range of vertebrate animals including birds, squirrels, porcupines, pangolins, lizards, turtles, badgers, civets, wild cats, monkeys, loris, wild boar, deer, serows, binturongs, gibbons, and bears have reportedly been hunted by Hmong groups (Johnson et al., 2003; Johnson et al., 2004; Tungittiplakorn & Dearden, 2002). Tungittiplakorn and Dearden (2002) undertook a detailed study of hunting and wildlife uses in two Hmong villages. Over a nine-month period they noted that not every species of animals were hunted for consumption by the Hmong. For example, the three Genera of civets (*Viverra* sp., *Paguma* sp., and *Paradoxuru* sp.) were hunted as pests as they attack domestic fowl and they are not usually consumed due to their strong scent. Wild dogs (*Canis* sp. and *Cuon* sp.) and cats (*Felis* sp.) are also not traditional sources of meat and are hunted as pests. It was noted that the Sumatran serow (*Capricornis sumatraensis*) is difficult to hunt due to the hilly terrain it inhabits. If a serow was hunted it was typically traded with the lowland Karen cultural group, as it has a strong odour. Although, some Hmong believe elements of the serow have medicinal qualities. Two species of bear, the sun bear (*Helarctos malayanus*) and Asian black bear (*Ursus thibetanus*), were also hunted for medical purposes by the Hmong. A roasted bear's gall bladder is believed to cure leprosy, measles, lung disease, and fever. The bones of the bear were ultimately sold to lowland pharmacies, however, due to the decline in the number of bears very few are hunted today. Wild pig (*Sus scrofa*) is the most intensely targeted species hunted by the Hmong. The meat from wild pig is usually consumed domestically and not sold or traded. Barking deer (*Muntiacus muntjak*) are also heavily hunted.

Some species, such as the pangolin (*Manis javanic*) and the monitor lizard (*Varanus bengalensis*), are hunted for the wildlife trade, and are not traditionally eaten by the Hmong. The meat from both pangolin and monitor lizard, and other animals that are eaten, including deer, civets, wild pig, squirrel, and loris, are sold to lowland Thai or Karen villages (Johnson et al., 2003; Srikosamatara et al., 1992). This trade is an important part of the Hmong economy during the dry season. However, Srikosamatara et al. (1992) state that wildlife trade of both live and dead animals poses a significant threat to wildlife in these regions, and the trade of some animals is now prohibited under Lao PDR law.

Today, the majority of Hmong men hunt with guns; although slingshots are still used, mainly by children, to hunt squirrels and birds (Johnson et al., 2003). Prior to the advent of World War II, when guns become more readily available, the vast majority of hunting was practiced with wooden cross-bows (Cooper, 1984, p. 119; Tungittiplakorn & Dearden, 2002). Other equipment used now includes a bamboo device that imitates the sound of deer calf in order to attract adult deer, dogs for tracking, fire to flush animals out of thick forest, traps, and spears (Tungittiplakorn & Dearden, 2002). Spears are mainly used to kill animals once they have been snared in traps (Tungittiplakorn & Dearden, 2002). No literature goes into any great detail about the types of spears used by the Hmong or what they are made from. We can only assume that spears are not commonly used for hunting due to the lack of literature on the subject. Today traps are second only to guns as the most common method of hunting among the Hmong (Johnson et al., 2003). Traps have been used for both large and small game; although traps for larger animals are less popular then they once would have been due to the decline in the number of larger animals and the increased use of guns (Tungittiplakorn & Dearden, 2002). Much of the knowledge on how to make traps has been lost, now only retained by the older men from Hmong villages (Tungittiplakorn & Dearden, 2002). Many traps for larger animals, such the *heo mii* trap, utilise a specialised snare for capturing bears. Other traps, including the *heo hao* trap, trip-wired spears, or gun traps are prohibited or controlled in countries of Southeast Asia (Johnson et al., 2003). Tungittiplakorn and Dearden (2002) have classified traps still used by Hmong villages in north Thailand today into six groups based upon their function: snares, spring lance, falling weight, glue trap, net, and self-triggering gun traps. Although many different traps (made from bamboo) have been used in the past, the knowledge of how to make and use these traps has almost been lost, as only the older men still know how to produce them.

2.3.4 Historical Roots of Lao-Isan Culture

There is an ongoing debate about the origins of the Lao-Isan Culture. Linguistic evidence, and to a lesser extent Chinese, Khmer and Indian historical texts, and Lao and Thai oral traditions, suggest the Lao-Isan people migrated from Southern China at the beginning of the first millennium AD (Myers, 2005). However, many Thai and Lao historians argue for an indigenous origin. They argue that Lao-Isan Culture entered history as a part of the early Khmer Empire, described as Chenla (550 to 802 AD) (Tossa, 1990, p. 16). In this hypothesis, Chenla was situated on the lower and middle Mekong, with its original centre located just below the mouth of the Mun River in Ubon Ratchathani Province, northeast Thailand.

Isan is also the name given to northeast Thailand and the description of the largest of the four geographic regions that make up the country of Thailand (Myers, 2005). Isan is also known geographically as the Khorat Plateau (as well as northeast Thailand). The Khorat Plateau is bordered by present-day Laos to the north and east, the Dangrek escarpment that separates Cambodia to the south, and to the west the Petchabun Ranges (Lefferts, 2005). The population of Isan consists predominately of Lao-Isan people, with Lao ethnic heritage integrated into the contemporary political system of Thailand (Lefferts, 2005). Despite external influences from other Southeast Asian cultures, Lao-Isan people maintain their own personal identity centred on a rural village existence (Myers, 2005).

2.3.5 Lao-Isan Subsistence Strategies in the Lowland floodplains

A typical Lao-Isan village is surrounded by wet-rice paddies and located near canals, ponds, dams and rivers for irrigation and the catching and gathering of fish and snails (Somnasang & Moreno-black, 2000). Rice is the foremost agricultural crop cultivated in northeast Thailand, however, only one crop can be produced a year because of low, unpredictable rainfall in this region of Thailand (Somnasang et al., 1998). Other areas of Thailand have heavier more predictable rainy seasons that can produce two or even three crops a season. Producing only one crop a season is a major economic restriction that ensures northeast Thailand remains the poorest region of Thailand (Somnasang et al., 1998). The Lao-Isan also cultivate other crops, such as banana, corn, cucumbers, asparagus, and other green vegetables, and rear domestic animals including pigs, chickens and ducks (Setalaphruk & Price, 2007; Somnasang et al., 1998). In addition, water buffalo and cattle are raised and herded around the villages and surrounding rice paddies (Setalaphruk & Price, 2007). In the remaining forested areas, rice paddies, and around the home, a vast array of wild plants and animals are gathered and hunted for a variety of purposes including food, medicine, crafts, building materials, and for religious ceremonies (Somnasang & Moreno-black, 2000).

Rural Lao-Isan people depend on hunting or gathering local wild food as an alternative to domesticated food, especially in low rice yield years (Somnasang et al., 1998). The frequency and the number of animals hunted depends upon seasonal variation and also the amount of free time available in-between other cultivation activities. A study by Kunarattanapruk et al. (1998) found that from the start of the wet season in May/ June, there are extended periods of free time between seeding the rice paddies and transplanting the young rice plants to hunt or gather resources from the local forest. In addition, the forest during these months is plentiful in both plant and animal resources. From July to September in the middle of the wet season, young rice plants are transplanted. This is a time consuming process, so few people hunt during these months. By October and November the wet season has ended and Lao-Isan people are busy harvesting rice, so only a select few members of a family gather forest food during these months. December to February, the first half of the dry season, people have more free time to utilise forest resources and by March and

April, the end of the dry season, people once again have free time. However, despite having free time, very few people go hunting or gathering during the end of the dry season due to the hot weather and decline in the number and diversity of plants and animals.

A 1998 study by Somnasang et al. investigated the local knowledge of wild food from twenty Lao-Isan villages located in Surin, Roiet, and Mahasarakam Provinces, northeast Thailand. The study found that men did the majority of the hunting and were experts at catching ground lizards, birds, rats, rabbits, snakes, jungle fowl, wild pigs, geckos, frogs, and toads. A similar study of the same year by Kunarattanapruk et al. (1998), focused on the frequency, variety, and amount of forest food resources consumed at a household level. The study measured the collected wild food consumption of seven households in one Lao-Isan village. The results demonstrated that by weight 35 per cent of all collected wild food consumed in the home, over the course of a year, are types of animals (Figure 18). The animals included insects, freshwater snails, frogs, toads, tortoise, ground lizards, tree monitors, tree lizards, doves, jungle fowl, squirrels, tree shrews, flying lemurs, rats, wild pigs, palm civet, and pangolin. Freshwater fish were also a percentage of the animals consumed, with identified species including silver barb (*Barbonymus gonionotus*), carp (Cyprinidae), snakehead murrel (*Channa striata*), rasbora (*Rasbora* spp.), walking catfish (*Clarias* spp.), Asian swamp eel (*Monopterus albus*), and the Nile tilapia (*Oreochromis niloticus*). The Nile tilapia was only introduced to Thailand from Africa in the 1960's (Piumsombum, 2001). Forty-nine taxa were recorded, demonstrating a much larger variety of animal species than that documented in Somnasang et al. (1998).

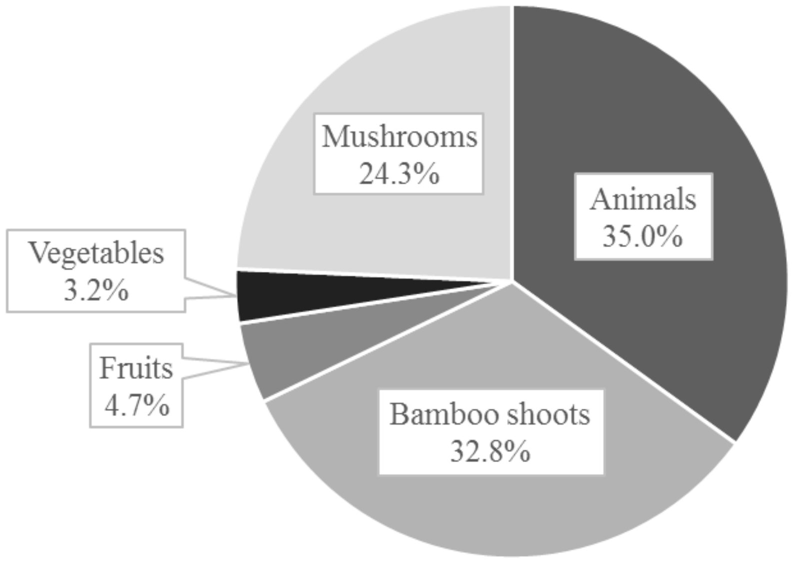


Figure 18: The relative frequency by weight of types of wild food collected for consumption in seven households of one Lao-Isan village, over the course of a year (After: Kunarattanapruk et al., 1998)

During a recent study of animals utilised by communities surrounding the Phon Songkhram community forest, north of the site of BNW (Figure 1), ten animals were identified as being hunted in recent memory (Table 1). The Phon Songkhram Community Forest project is outlined in *Chapter 1: Introduction 1.4.2 Phon Songkhram Community Forest Project*. All of the animals identified were medium or small mammals. The absence of large game is due to the lack of suitable habitat in the area.

Table 1: Mammal species identified in the Phon Songkhram Community Forest (W. Phanurak, personal communication, February 8, 2013)

Taxon	Common name
Canis aureus	Golden jackal
Lepus peguensis	Siamese hare
Callosciurus finlaysonii	Variable squirrel
Tupaia belangeri	Northern treeshrew
Viverricula indica	Small Indian civet
Viverra zibetha	Large Indian civet
Herpestes javanicus	Small Asian mongoose
Rattus rattus	Black rat
Paradoxurus hermaphroditus	Common palm civet
Paguma larvata	Mask palm civet

It is remarked by Somnasang and Moreno-black (2000), and Setalaphruk and Price (2007), that wild foods (both plants and animals) have both medicinal and spiritual significance for the Lao-Isan people. The use of plants by local folk healers is expanded upon further by Khongthon and Chang (2016). The article examines the plants used by traditional folk healers and the transfer of knowledge within fifteen villages in the Phon Songkhram sub-district, northeast Thailand.

It is assumed that small rodents that would be an agricultural pest when growing and storing grain are hunted for the dual purposes of pest control and food consumption. Somnasang et al. (1998) mentions that Lao-Isan villages only eat rats that live in the rice paddies and they do not eat house rats because they are considered dirty. In addition to pest control and food consumption, there are also economic incentives for hunting; the animals that are hunted and gathered by Lao-Isan villages are sold at local markets, which provide a second source of income for a household (Moreno-black et al., 1996). Meat is traded within an individual’s village or to a neighbouring village (Somnasang & Moreno-black, 2000).

How an animal is hunted or gathered by the Lao-Isan depends on its size, or occasionally species, and the type of equipment available. Guns, blowpipes constructed of bamboo, cross-bows and slingshots are all used to shoot birds. However, when using traps for birds different techniques are required for different types (Somnasang et al., 1998). For example, songbirds from the Passeriformes order are caught using a decoy bird placed in a cage. The singing of the decoy bird attracts other birds, which are then caught in a net (Somnasang et al., 1998). Another method is to pursue birds during the dry season through sugarcane fields. A large net is setup between two poles, and when a flock of birds comes to rest on the sugarcane a group of men chase them towards the net, where they are caught (Somnasang et al., 1998). Nets are also used to catch rats and rabbits, by placing a small baited net on the ground in which they are caught (Somnasang et al., 1998). Lao-Isan communities also use traps and nets to catch freshwater fish in rivers, ponds, and rice fields (Little et al., 1996). An array of bamboo traps are used for fishing in northeast Thailand (Somnasang et al., 1998).

Rats and ground lizards are often hunted using a slingshot, and many different sorts of bamboo traps, including snares. However, no literature classifies or explains how these traps work in any great detail (Somnasang et al., 1998). There is also a lack of literature on how larger animals, such as tree monitors, palm civet, pangolin and wild pigs, are hunted or trapped.

Pellet bows are also used by Lao-Isan villagers for hunting rats and birds (White, 1982). Pellet bows are common in many parts of Asia and are a wooden bow with a small woven or animal hide pouch in which a clay pellet, approximately 1cm in diameter, is placed. An archer then draws the bow back, and the projectile is launched toward the target (Hawtrey, 1901; Peiser, 1996). Kiln-fired pottery pellets are used as ammunition for pellet-bows (White, 1982). The majority of the literature on pellet-bows from Lao-Isan villages in northeast Thailand comes from archaeological papers.

2.4 DISCUSSION: INTERPRETING SUBSISTENCE STRATEGIES PAST AND PRESENT

This chapter has shown the diversity of terrestrial and aquatic fauna found in present day northeast Thailand. The variety of fauna, and the environment in which the fauna occupied, provides valuable information and context for studies of the zooarchaeological record and subsistence strategies. However, the past environment and fauna is very different to the present day, due to climatic changes, modern intensive agriculture and hunting. Some of these change in fauna can be seen in the zooarchaeological record. For example it has been noted that the size of fish bones at sites in northeast Thailand are substantially larger in comparison to present day examples, due to modern overfishing (Thosarat, 2004, pp. 175-176). Likewise, the presence of animals such as tiger, rhino, and Asian elephant in the zooarchaeological record, which are now extinct from the region. It is important to note that the animal remains from archaeological sites offer insight into past ecosystems, and the types of fauna present. Nevertheless, these remains cannot be used to reconstruct past environments or animal population sizes, due to socio-cultural aspects of subsistence strategies.

The evidence from pre-historic sites in Southeast Asia has provided comparative examples and findings regarding the development of subsistence strategies over time. This background research also provides a valuable insight into faunal analysis methods and approaches (Table 2). The pre-agricultural inland rock-shelters and cave sites of inland Thailand show the subsistence strategies focused on the hunting of larger game animals (Sarasin, 1933; Shoocongdej, 2006; Sørensen, 1979; Van Heekeren & Knuth, 1967). Whereas Thai-Malay Peninsula pre-agricultural strategies tend to utilise aquatic resources and slow moving fauna that would have been gathered rather than hunted. The coastal hunter gather societies of Thailand also heavily depended on gathering slow moving fauna such as turtle, tortoise, and shellfish (Conrad, 2015). The link between the slow moving easily acquired resources and the onset of agricultural prehistoric societies in Southeast Asia warrants further discussion (Conrad, 2015).

Zooarchaeological studies from northeast Thailand have illustrated that at the sites of Ban Chiang, Ban Na Di, Non Nok Tha, Ban Lum Khao, and BNW people in the past practised a broad range of subsistence strategies. These included hunting, fishing, and gathering of wild animal resources, as well as the raising of domestic pig, cattle, dog, and rice cultivation (Table 2) (Bayard et al., 1982; Higham, 2004a; Higham, 2012a; Higham & Kijngam 1979; Higham & Kijngam, 1984; Higham & Thosarat, 2012; Iseppy, 2012; Kijngam, 2010; Thosarat, 2004; Thosarat, 2010; Thosarat, 2012; Thosarat, 2012a). This is in contrast to the agricultural societies of Man Bac and An Son in Vietnam, where domestic animals were the main subsistence focus (Piper et al., 2014; Sawada et al., 2011). In a few sites in northeast Thailand the meat from wild animals was more than just a supplement, it provided a subsistence staple. The Neolithic layers at BNW show a strategy focusing on hunting, fishing, trapping, and gathering of shellfish, turtle, and tortoise (Kijngam, 2010; Thosarat, 2010). In fact, deer, fish, turtle and tortoise NISP outnumbered domestic resources in this period at BNW. However, the Iron Age site of Noen U-Loke, west of BNW, showed low numbers of wild animal resources and high quantities of cattle remains (McCaw, 2007). People at Noen U-Loke possibly specialised in just one variety of domestic animal during the Iron Age. While, the Iron Age people at BNW continued hunting, fishing, and trapping, with deer and fish remains found in all layers of the site.

Table 2: The sampling methods, quantification techniques, and types of fauna found at the sites mentioned in this chapter

Sites	Date	Time Period	Site Type/ Environment	Sampling Methods in the Literature	Faunal Data	Domestic Animals	Wild Animals	Fish	Shellfish	Marine Animals	References
Vietnam											
An Son	c.2100BC - 1050BC	Neolithic	Mound - Riverine or estuarine	In situ recovery during excavation. Soil samples from trench, 2 were wet-sieved through a 2-mm mesh. No samples from trench 1 or the trial trench were wet sieved.	NISP	✓	✓	✓	✓	×	Bellwood et al., 2011; Piper et al., 2014
Man Bac	c.1800 - 1500BC	Neolithic	Open - Coastal and estuarine	In situ recovery during excavation, sieving and wet sieving of two excavation squares (squares E3 and G1). It is noted that it is likely that some very small vertebrate remains may have been missed.	NISP MNI	✓	✓	✓	✓	✓	Sawada et al., 2011; Toizumi et al., 2011
Cambodia											
Samrong Sen	c.1650BC - 200BC	Neolithic, Bronze Age	River bank shell midden – Inland riverine	In situ recovery during excavation. The absence of fish remains indicates that no sieving or wet sieving was done.	Presence and absence	✓	✓	×	✓	✓ Shellfish	Mansuy, 1902; Mansuy, 1923

Phum Snay	c.500BC – 500AD	Iron Age	Mound - Inland riverine	In situ recovery during excavation. Bones were used from burials and non-burial contexts. Small bones were collected from the flotation sample. Soil samples were kept for future flotation.	NISP MNI	✓	✓	✓	✓	×	O'Reilly et al., 2006; Voeun, 2008
Western Thailand											
Sai Yok	_	Hoabinhian-Holocene	Rock-shelter – Inland mountainous	In situ recovery during excavation.	Presence and absence	×	✓	×	✓	×	Van Heekeren & Knuth, 1967
Eastern Thailand											
Nong Nor	2450BC 1100BC - 700BC	Hunter-gatherer and Bronze Age	Flood plain - Coastal and estuarine	In situ recovery during excavation. Dry sieved all contexts and wet sieving a sample. In the Bronze Age context fauna remains were only reported on from burial contexts.	NISP	✓ Only Bronze Age contexts	✓	✓	✓	✓	Higham, 1998; O'Reilly 1998a
Khok Phanom Di	c.2000BC - 1500BC	Hunter-gatherer	Mound - Coastal and estuarine	In situ recovery during excavation. Dry sieved all contexts. Wet sieved and flotation samples used.	NISP MNI	×	✓	✓	✓	✓	Grant & Higham, 1991; Kijngam, 1991; West, 1991

Northeast Thailand											
Ban Chiang	c.2000BC - 200AD	Neolithic, Bronze Age, Iron Age	Mound - Inland Riverine	In situ recovery during excavation. Dry sieved all contexts and wet sieving a sample of each feature and spit.	MNI Changes over time	✓	✓	✓	✓	×	Higham & Kijngam 1979; White 1982
Ban Na Di	c.700BC - 500AD	Bronze Age, Iron Age	Mound - Inland Riverine	In situ recovery during excavation. Dry sieved all contexts through a 20mm mesh. A sample of each feature and spit was wet sieved through a 1mm mesh.	NISP MNI (by layer)	✓	✓	✓	✓	×	Higham & Kijngam 1984
Non Chai	c. 400BC - 200AD	Iron Age	Moated Mound - Inland Riverine	In situ recovery during excavation. The presence of fish remains indicates that wet sieving was done.	MNI (by layer) Presence and absence	✓	✓	✓	✓	×	Bayard et al., 1985
Non Nok Tha	c.1300BC - 970BC	Bronze Age	Mound - Inland Riverine	In situ recovery during excavation. The presence of fish remains indicates that wet sieving was done.	MNI (by layer)	✓	✓	✓	✓	×	Bayard, 1970; Higham, 1975
Ban Lum Khao	c. 1100BC - 550AD	Late Neolithic, Bronze Age, Iron Age	Mound - Inland Riverine	In situ recovery during excavation. Dry sieved all contexts. Wet sieved contexts. Wet sieved and flotation samples used.	MNI (by layer)	✓	✓	✓	✓	×	Higham, 2004a; Thosarat, 2004

Noen U-Loke	c. 380BC - 500AD	Iron Age	Moated Mound - Inland Riverine	In situ recovery during excavation. Dry sieved all contexts. Wet sieved and flotation samples used.	MNI (by layer and feature)	✓	✓	✓ Mostly mortuary contexts	✓	×	McCaw, 2007; Thosarat, 2007
Ban Non Wat	c.1750BC - 500AD	Neolithic, Bronze Age, Iron Age	Moated Mound - Inland Riverine	In situ recovery during excavation. Dry sieved all contexts. Wet sieved and flotation samples used.	MNI (by layer and feature)	✓	✓	✓	✓	×	Higham, 2012a; Iseppy, 2012; Kijngam, 2010; Thosarat, 2010; Thosarat, 2012; Thosarat, 2012a

2.4.1 Hmong and Lao-Isan in an Archaeological Context

The review of the Hmong and Lao-Isan has revealed socio-cultural aspects of subsistence strategies, such as seasonality, ecology, trade, and hunting techniques. It has highlighted that the relatively low intensity swidden agriculture used by the Hmong allows hunting practices to be carried out all year round (Johnson et al., 2003). In comparison, the high intensity paddy farming of the Lao-Isan cultures limits available time for hunting to a third of the year (Kunarattanapruk et al., 1998). This illustrates that the agricultural mode has important implications for interpreting the zooarchaeological record in prehistoric sites in Southeast Asia. It would be expected that if the agricultural mode modified or intensified the subsistence strategies would change, and therefore the zooarchaeological record would also change. The subsistence system is also clearly influenced by ecological factors, such as the diversity and availability of animals, with the Hmong hunting a greater diversity and higher proportion of large mammals due to the remaining forest cover in the highlands. The extensive use of traps by both groups has shown their importance as a hunting technique, and should not be overlooked in an archaeological context. This comparative cultural study of modern ethnic groups will be a useful resource in interpreting the subsistence strategies of prehistoric sites in northeast Thailand during *Chapter 6: Discussion* in this thesis. However, when applying an ethnographic perspective to an archaeological context, one should not assume a direct link exists between past and present practices. Rather, that the comparative cultural study allows the researchers to consider alternative explanations for what is seen in the archaeological record.

The studies of the Hmong provide a good overview of animals targeted by hunters, and the techniques used to hunt animals. A smaller body of work focuses on ecology, economics, and animal husbandry (Delang, 2002, and Sodarak, 1999). In comparison, the literature on Lao-Isan subsistence practices centres upon local knowledge of hunting and gathering of wild food (both plants and animals) as a seasonal economic resource (see Kunarattanapruk et al., 1998; Somnasang et al., 1998; Somnasang & Moreno-black, 2000). Only fragments of information on what techniques are used to hunt are provided. The literature supplies data on economic drivers, such as the sale at local markets, or household consumption (see Moreno-black et al., 1996; Somnasang & Moreno-black, 2000). Traps are the second most extensively used hunting technique among both the Hmong and Lao-Isan cultures for hunting large animals, such as deer, wild boar, and monkeys (predominately the Hmong), small mammals, and birds (both Hmong and Lao-Isan). These are second only to the use of guns (Johnson et al., 2003; Somnasang et al., 1998; Tungittiplakorn & Dearden, 2002). Despite their extensive modern use organic traps have been largely overlooked in the archaeological record. This is predominately due to the short life-span of organic traps, which decay rapidly in a tropical environment. Also overlooked in archaeological contexts are organic cross-bows, sling shots, and pellet bows, currently used in contemporary hunting by both the Hmong and Lao-Isan groups (Somnasang et al., 1998; Tungittiplakorn & Dearden, 2002). Similar to traps, few signs of these contemporary hunting tools show up in the archaeological record, due to poor preservation of wood and other organic material. Clay bow pellets are the one exception to this, and are found throughout archaeological contexts at several sites in Southeast Asia (Bellwood et al., 2011; Higham, 2009; O'Reilly, 2006; White, 1982).

The zooarchaeological assemblage only provides part of the information on past subsistence, and is to a large extent a derivative of cultural practice. Incorporating contemporary subsistence strategies, and related material, into zooarchaeological analysis can reveal further information about diet and nutrition, food processing, animal husbandry, hunting practices, belief systems, and seasonality, which is a central part of any zooarchaeological analysis.

Chapter 3: Theoretical Approach

Theory is an essential part of zooarchaeological research, and has significant implications for how faunal remains are analysed within any given context. The majority of faunal analyses are interpretations based on biological, ecological and social-cultural theories (Reitz & Wing, 2001, p. 252). This chapter begins with an exploration of subsistence theories and models within the field of archaeology. Middle-range theory and the use of ethnography in interpreting the archaeological record is discussed. This is followed by an examination of comparative cultural studies, and the integration of modern case studies and ethnographic literature into zooarchaeological research. Lastly, the three major theories for social change in Southeast Asia, hierarchy, heterarchy, and the integrated social change theory, are explained. How the four theories for social change can be recognised in the zooarchaeological assemblage is outlined. This chapter ends with a summary of the major theories that will be applied or tested throughout this thesis.

3.1 SUBSISTENCE THEORIES

The primary goal of the zooarchaeological research is to interpret the relationship between people and animals, based on biological, ecological and cultural factors (Reitz & Wing, 2001, p. 252). The use of animals for subsistence is one of the ways zooarchaeologists interpret this complex relationship. Subsistence studies focus on the economic and biological aspects of subsistence, such as human nutritional requirements and the nutritional contribution of a specific animal taxa. Two of the most widely applied approaches in subsistence studies are game theory and the optimal foraging model (Reitz & Wing, 2001, p. 22, and 253). These theories are focused on the economic costs and benefits of obtaining a food resource in the form of costs; time, risk, or energy expended and benefits; calories gained, safety, or time saved (Reitz & Wing, 2001, p. 22). Optimal foraging models argue that humans make rational decisions to maximise their energy intake, which is often measured in calories (see Hawkes et al., 1982; Nagaoka, 2002; Winterhalder, 1981).

The study of subsistence strategies is less about the economic costs and benefits of obtaining a food resource, and more about the strategies employed by people to actively obtain resources. These studies look at how resources are actively managed by people, and the techniques used to acquire, control, and process them (Reitz & Wing, 2001, p. 257). Subsistence strategy studies in mainland and island Southeast Asia are often driven by cultural ecology or an ecological anthropology premise. For example Piper and Rabett's (2014, p. 121, 133) study on late Pleistocene subsistence strategies in island Southeast Asia maintains that the early inhabitants of Niah Cave in Sarawak, Malaysia would often employ foraging and hunting strategies adapted to the surrounding dense tropical rainforest. Throughout the occupation of Niah Cave the faunal record reveals a strategy centred on the wild bearded pig (Sus barbatus). It is suggested that a likely method used to hunt the pigs was traps set along well tracks, taking advantage of the bearded pig's behaviour of using established tracks to move though the undergrowth. The next most common taxa identified at Niah Cave was monkeys (Piper and Rabett 2014, p. 133). The presence of monkeys and orangutan is an indication the people had hunting or foraging technology to exploit the arboreal ecological niche where these animals live. It was concluded that the people who inhabited Niah Cave were very aware of the ecological niche in which an animal would live and developed techniques to exploit this (Piper and Rabett 2014, p. 133).

Studies that use cultural ecology or an ecological anthropology premise often overlook aspects of human behaviour like cultural history, symbolism, and ideology. Likewise, research using game theory and the optimal foraging model leave out sociocultural factors such as ritual, politics, and religion (Reitz & Wing, 2001, p. 25). Many recent studies of subsistence strategies have addressed this by including comparative cultural studies into their interpretations. This is discussed further in *3.2 Comparative Cultural Studies* below.

3.1.1 Subsistence Strategies and Middle-Range Theory

Subsistence strategies as a theme in archaeology become more common in the 1960's to 1970's as the field moved away from a culture history paradigm toward a sociocultural understanding of artefacts (Dunnell, 1978). In contrast, faunal analysis centred on the creation of taxonomic lists and the identification and description of skeletal elements alone. As stratigraphic dating improved with the introduction of radiocarbon dating, increasingly more importance was placed on past environments, diet, and human behaviour (Brewer, 1992). Archaeologists realised that they could no longer interpret the archaeological record in isolation and that different types of human behaviour can leave unique archaeological signatures.

A turning point was the introduction of processual archaeology theories or "new archaeology". Under processual theories the archaeological record was understood as an incomplete anthropological record (Binford, 1962, Dunnell, 1978; Phillips & Willey, 1953). In order to interpret the archaeological record as a socio-cultural phenomenon it was necessary to have analogies between human behaviour and the archaeological record. The new approach meant that the archaeological record could be understood through the use of anthropological theory. These approaches are referred to as culture reconstruction and later behavioural archaeology (Dunnell, 1978; Schiffer 1976).

A good example of the new approach is Binford's (1980) acritical on a hunter-gatherer Nunamiut group in north-central Alaska. Working within a behavioural archaeological framework Binford (1980) interpreted settlement patterns based on certain environmental variables. He related subsistence strategies to inter site assemblage variability and links these strategies to different environmental conditions. The article raised two important concepts, firstly not all hunter-gatherer groups share a similar basic organisation, and secondly, differences in organisation can have a predictable effect on the archaeological record.

Binford's (1980) work employs a middle-range theoretical approach (Raab & Goodyear, 1984). Middle-range theory uses empirical observations to explain the processes and principles responsible for the formation of the archaeological record in order to interpret, human behaviour and human relationships with the environment (Reitz & Wing, 2001, pp. 21-22). The theory was developed in sociology in the late 1940s as there was a need for a unified sociological theory (Merton & Merton, 1968). One of the first mentions of middle-range theory in the archaeological literature was in Binford's (1977, pp. 1-10) in which he concludes;

> "*we must develop ideas and theories (middle-range theory) regarding the formation processes of the archaeological record. Only through an accurate understanding of such processes can we reliably give meaning to the facts that appear, from the past, in the contemporary era.*" Binford (1977a p. 7).

Binford continued to develop the concepts of middle-range theory into the 1980's (Binford 1980, Binford 1981).

Although middle-range theory explains some of the social organisational patterns we can observe in the archaeological record, the approach fails to explain all aspects of behaviour that are integral to anthropology. The approach is frequently based on observations by archaeologists during field work, which creates the potential for causal statements about aspects of human behaviour and social organisation, when interpreting the archaeological record. An example of the uses of middle-range theory in Southeast Asia is in White's (1982: p. 93) and more recently Higham's (2010 p. 127) interpretation of pottery pellets from sites in northeast Thailand. Both reports mention the present day use of kiln-fired pottery pellets as ammunition used in pellet-bows by Isan villagers to hunt rats and birds. The observation of contemporary uses of pellet-bows at the archaeological sites is then applied to the interpretations of pottery pellets found at archaeological sites. However, no details of sociocultural context is provided. The use of middle-range theory in White's (1982) and Higham's (2010) reports might not have been a conscious decision. Middle-range theory is often applied to an archaeological context unconsciously or without reference to the theory, due to it been based on causal observations (Herbert, 1996).

Research by Gifford-Gonzalez's (1991) critiques models based on Binford's (1980) work. The research states that zooarchaeologists have become accustomed to high levels of confidence in their inferences about the human behaviour and social organisation when interpreting animal remains. The confidence is in part due to the causal and functional links between the zooarchaeological record and the processes and contexts which generate them (Gifford-Gonzalez, 1991). This research highlighted the need for different approaches with new relational analogies, drawn from a wide variety of sources.

3.1.2 Comparative Cultural Studies

Due to the limitations and problems with causal analogies in middle-range theory in the 1990s and 2000s zooarchaeology moved away from the approach and focused on theories and models from cultural anthropology. Cross-cultural studies or comparative cultural studies have provided important data on contemporary practices that can be quantified and assist in our understanding of the archaeological record (Reitz & Wing, 2001, p. 22). There are mainly four main types of comparative cultural studies; Cross-cultural comparisons consider a broad sample over a large geographic area, often worldwide, and the data used can be from primary field studies or secondary sources such as ethnographies, censuses, and historical documents (Ember & Ember , 2009 p. 16). Comparison of case studies is narrower than the worldwide cross-cultural comparison and the data comes from ethnography and case studies (Ember & Ember, 2009 p. 17). Cross-historical studies, which are often restricted by particular times and places and use historical documents as their main data (Ember & Ember, 2009 p. 18).

Comparative cultural studies explore the association between material culture and human behaviour in modern societies to explain material recovered from archaeological sites. Ethnographic information yields important details of human interactions with animals. The use of ethnography in archaeological comparative studies is sometimes referred to as ethnoarcheology (Reitz & Wing, 2001, p. 145). Mutundu's (2005) ethnoarchaeological study of herd management practices used ethnographic observations to inform interpretations of archaeological contexts. The research compared the age profiles of domestic stock from East African Neolithic sites and contemporary pastoral Maasai settlements in southern Kenya. The age profiles from the Neolithic sites and those of contemporary Maasai settlements were very similar. This supports the hypothesis that the subsistence and herd management practices at some East African Neolithic sites may have been similar to contemporary examples (Mutundu, 2005). Although some of the similarity in underrepresented age categories may partly be due to taphonomic processes and sampling factors. However, these factors likely only had a limited influence on the numbers of the age profiles (Mutundu, 2005).

Shoocongdej (1996) maintains that researchers of Thai prehistory must adopt a problem-oriented approach that establishes a link between our conceptual archaeological framework and comparative cultural studies. The approach should develop models and methodological procedures to explain and identify past human behaviour and archaeological material using various sources of comparative cultural studies (Shoocongdej, 1996). The approach is particularly relevant for northeast Thailand where contemporary hunting is still practiced seasonally, and is strongly linked to a tradition of seasonal agriculture. Recent studies by Yankowski & Kerdsap (2013), and Yankowski et al. (2015) have adopted a cultural comparative approach to their research on prehistoric salt sites in northeast Thailand. These ethnoarchaeological case studies on local salt resources and salt-making were completed in order to gain a greater insight into prehistoric salt sites and features related to salt production found in prehistoric sites in northeast Thailand (Yankowski & Kerdsap, 2013). Additionally, archaeological, historical, and ethnographic data was used to investigate salt fermented fish production, addressing how foods and preparation methods can be identified in the archaeological record (Yankowski et al., 2015).

Ethnographic data yields important details of human interactions with animals, although it must be remembered that people living today are not a direct analogue to those in the past (Reitz & Wing, 2001, p. 145). Examining the relationship between material and human behaviour in contemporary societies can provide alternative interpretations about food management practices, production, and ritual association applicable to material recovered from archaeological sites. As archaeologists we need to consider the human behaviour and culture that the archaeological record represent, ethnographic data provides a valuable key to this challenging undertaking.

3.2 SOCIAL CHANGE THEORIES IN SOUTHEAST ASIA

Social change has been defined as ‘the alteration of the social structure within a society’ (Van Krieken et al., 2013). Models of social change are based on different triggers that alter organisation (Renfrew & Bahn, 2008). An example of such a trigger for social change is social revolution; a theory which is explored in Marxism (Layder, 2006). Other examples include economic triggers; where social change occurs due to shifts in elite structure, such as changes in trade networks (Renfrew & Bahn, 2008). Additionally, environmental triggers including climate change have also been used to explain social change (Boyd & McGrath, 2001). It has been noted that a major shift in complexity occurred in the Mun River Valley; from low-density subsistence settlement in the Bronze Age to the high density settlement town-based Iron Age society (Boyd & McGrath, 2001). In order to explain the shift in complexity from the Bronze Age to Iron Age in Southeast Asia four major social change theories can be deployed: *hierarchical* model (Glover, 1990; Higham, 1989, p. 154; O’Reilly, 2008), *heterarchical* model (Eyre, 2010; O’Reilly, 2000; White, 1995), *the integrated social and environmental mutual change* model (Boyd & Chang, 2010), and *ritual feasting model* (Hayden, 2003).

3.2.1 Hierarchical Model

The Hierarchical model originated from a cultural evolutionary approach, which argues a linear progression towards a more socially complex society (Renfrew & Bahn, 2008). The archaeological evidence used to support a hierarchical model within Thailand includes the appearance of luxury craft items, metal-working, elite burials, and the construction of ditches at sites during the early Iron Age (Higham, 1989, pp. 153-154; O’Reilly, 2000). The zooarchaeological evidence for a hierarchical model of complexity focuses on the placement of the domestic animals, including pig and cow, in burial contexts (Higham, 1989, p. 155). It also emphasizes the increasing use of domestic animals, the intensification of agriculture, and an increase in ritual feasting linked to mortuary rituals. If hierarchy were the basis of social change in Southeast Asia, one would expect the zooarchaeological record to show a decline in the use of non-domestic animals, and an increase in domestic animals as it moved from a village based society towards a town based society in the Iron Age.

3.2.2 Heterarchical Model

The heterarchical approach provides an alternative to the hierarchy model, by considering a series of overlapping links (including some hierarchical links), which reorganise over time (Crumley, 1995). The evidence associated with a heterarchical model within Thailand includes sub-regional ceramic variations, economic specialisation, differences in settlement strategies, and a lack of warfare (Onsuwan, 2003; White, 1995). Under the heterarchical model the zooarchaeological record would be varied across different sites in the same region during the same time periods. Some sites that become more specialised in a craft activity and/or differences in settlement strategies that utilise animals, which would be reflected in the zooarchaeological record.

3.2.3 The Integrated Social and Environmental Mutual Change Model

The integrated social and environmental mutual change model focuses on the integrated influence of socio-environmental processes, rather than socio-cultural or environmental processes alone (Boyd & Chang, 2010). The model considers the landscape as a socio-environmental construct, which may influence changes in social and/ or environmental behaviour. This approach is purposely non-deterministic, as there may be many possible trajectories both social and environmental. Support for the model within Thailand centres upon the use of natural resources, including animal resources, and changes in patterns of landscape occupation (Boyd & Chang, 2010). If the integrated social and environmental mutual change model was verified, changes in the animals hunted, and the season in which hunting occurred, may correspond with environmental events, such as the deteriorating environmental conditions at the onset of the late Holocene or social triggers such as the introduction of metallurgy (Boyd & Chang, 2010).

3.2.4 Ritual Feasting Model

The ritual feasting model has been proposed as a major factor in the intensification of production, leading to the domestication of plants and animals around the world (Hayden, 2009; Spielmann, 2002). This model often focuses on the social changes from pre-agricultural hunter-gatherer societies to farming societies. The ritual feasting model uses an ethnoarchaeological approach to develop models of community organisation that are relevant to understanding prehistoric village life

(Hayden, 2003). Ethnographic case studies within Southeast Asian cultural groups are used to demonstrate that all the domesticated animals, and the most important of the domesticated plants, are primarily or exclusively used in feasting contexts. It establishes that feasting generates powerful social factors that intensify and increase resource production of luxury foods as well as staples. The social factors include social and political ties, relationships within communities, competition between communities, and cooperative labour-intensive projects (such as house building, irrigation works, planting and harvesting) (Hayden, 2003). The zooarchaeological evidence for the ritual feasting model includes an increase in feasting activity (possibly seasonally if related to harvesting), and a change from staple foods to luxury foods items such as domesticated animals. Although other models incorporate ritual feasting and luxury items as evidence of social change, the ritual feasting model poses that ritual feasting, and related subsidence practices, are the triggering factor in such change.

3.3 DISCUSSION AND SUMMARY

This chapter has outlined several theories and models related to the study of subsistence strategy. Currently, subsistence strategy studies in Southeast Asia are predominantly driven by cultural ecology or an ecological anthropology premise. However, these premises often overlook aspects of human behaviour. Similarly, research using game theory and the optimal foraging model exclude sociocultural factors (Reitz & Wing, 2001, p. 25). Early work by Binford (1980) on the theory of middle-range was a necessary step in order to better understand the archaeological record as a socio-cultural phenomenon. However, the theory fails to explain all aspects of human behaviour, due to causal statements based of field observations. Some researchers have noted that middle-range theory has an important role to play in the future of archaeology as we return to the “big-picture” issues of human history (Herbert, 1996). Although, such broad theories of human behaviour are not easily tested, understanding the use of middle range theory will allow the development of a testable hypotheses (Herbert, 1996).

Due to the limitations and problems with the causal analogies in middle-range theory, comparative cultural studies are now integrated into zooarchaeological research. Integrating comparative cultural research into studies of subsistence strategy involves the use of modern case studies, ethnographic literature, and historical documents. A degree of caution is required when drawing conclusions from a modern context, which has a very different social, political, economic, and environmental context from prehistory. When applying comparative cultural research to an archaeological context it is not assumed a direct link exists between past and present practices, rather a comparative cultural study allows researchers to think of alternative explanations for what is seen in the archaeological record. These explanations or hypothesis can, in turn, be tested (Albarella, 2011). It is important that researchers of Thai prehistory adopt an approach that establishes a link between our conceptual archaeological framework and comparative cultural studies (Shoocongdej, 1996). A comparative cultural study of two groups; The Hmong and Lao-Isan cultures, chosen due to their dissimilar agricultural and environmental backgrounds, will be investigated as part of this thesis. Additionally, current models of social change in Southeast Asia, the hierarchical, the heterarchical, the integrated social and environmental mutual change model, and the ritual feasting model will be examined against the findings of this thesis in order to address the third objective outlined in *Chapter 1: Introduction 1.2 Objectives*.

Chapter 4: Methods

This chapter outlines the excavation and screening methodology employed at the sites of BNW, BSL, and NHR. Also presented here are the post-excavation zooarchaeological analysis of animal remains, including taxonomic classification, measurements taken, and age at death estimates. The methods used to quantify the data include the Number of Identified Specimens (NISP) and Minimum Number of Individuals (MNI). These methods are explained in this chapter. Additionally, the ethical considerations when working with animal remains are discussed at the end of this chapter.

4.1 EXCAVATION METHODOLOGY

The excavation of all three sites was undertaken using the stratigraphic system. Ten centimetre spits were utilised. After the spit was removed, the features and artefacts present were recorded and mapped. Surface and feature heights in relation to the datum point were recorded. A new layer was recorded where there was a distinctive change in soil type. Each context (spit, layer, and feature) was recorded on a context form and given a unique context number and description. Artefacts (bangles, beads, pendants, clay pellets, other clay objects, burnishing stones, stone anvils, slag, bronze objects, bronze fragments, iron objects, iron fragments, conical rollers, spindle whorls, worked bone, worked stone, and whole pots) were given an artefact number and recorded on an artefact form. The animal bone, shells, pottery sherds, and stones were recorded with their corresponding context number. Burials were recorded on a separate recording form and given their own unique burial number. Grave goods were given an artefact number and also a burial number. Animal bones associated with burials and the burial fill were recorded with their corresponding burial number.

4.1.1 Excavation Units

The excavation of three sites in northeast Thailand was carried out over four seasons from 2007 to 2011. Sixteen excavation units were opened across the site of BNW, an additional two units were opened at the site of NHR, and one unit at the site of BSL (Figure 19, Figure 21, and Figure 22). Some excavation units were individual isolated squares, whilst others were excavated alongside each other, forming a joint, larger excavation square (Figure 20). During the first excavation season, December 2007 to February 2008, four 4x4 meter excavation units (G104, N100, T200, and Z201) and a 4x4 meter L-shaped excavation unit that joined T200 (TU199-200), were excavated at Ban Non Wat.

In the second season, December 2008 to February 2009, seven units at BNW were excavated. These included two 4x4 meter units joined together (O300 and P300), with a 1x1 meter test pit unit (N300) joined to the northwest conner of O300 and P300, a third 4x4 meter unit on its own (S400), an L-shaped unit that joined T200 and TU199-200 (U200), a 4x4 meter unit (V200), and a 2x4 meter unit (W200) which was joined to T200 and TU199-200. In the third season, December 2009 to February 2010, another four units were opened at BNW and one unit at BSL. At BNW three joined units were excavated: two 2x2 meter units (I500 and J500) and a 4x4 meter unit (K500). A further 4x4 meter unit (N96) was also opened at BNW. At BSL, a 4x4 meter unit (M100) was opened during this season. During the fourth season, December 2010 to January 2011, units N300, O300, P300, and K500 from the previous seasons were completed and two new 4x4 meter units (H100 and I100) were opened at the site of NHR.

Figure 19: The location of the sixteen excavation units at BNW (in yellow)

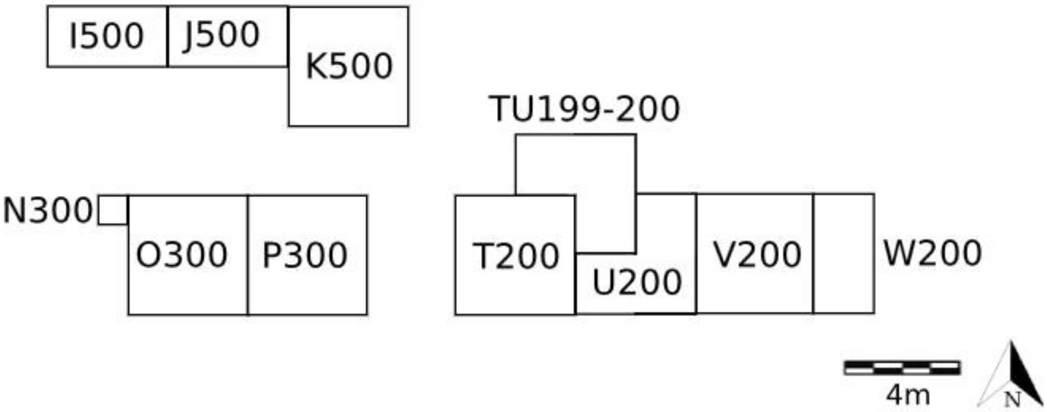


Figure 20: The layout of the grouped excavation units at BNW (not showing location relative to one another).

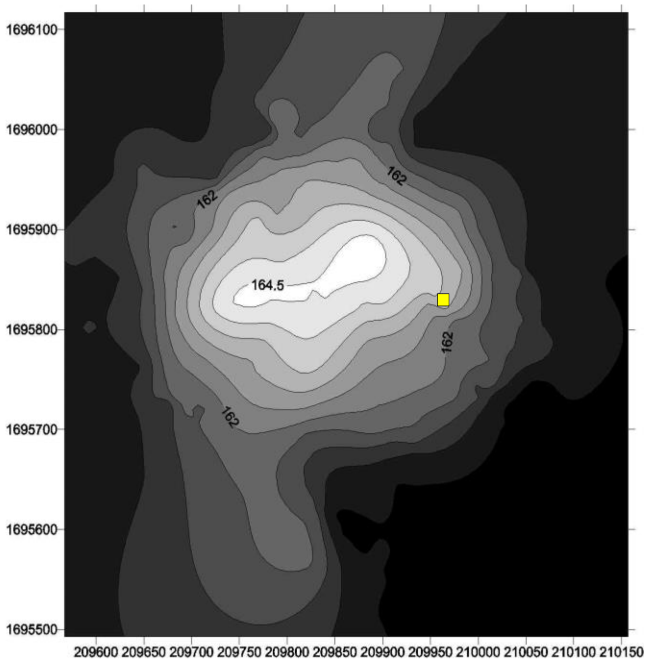


Figure 21: The location of the single unit at BSL, excavated in 2009/ 2010 (yellow) (prepared by Chang, 2010).

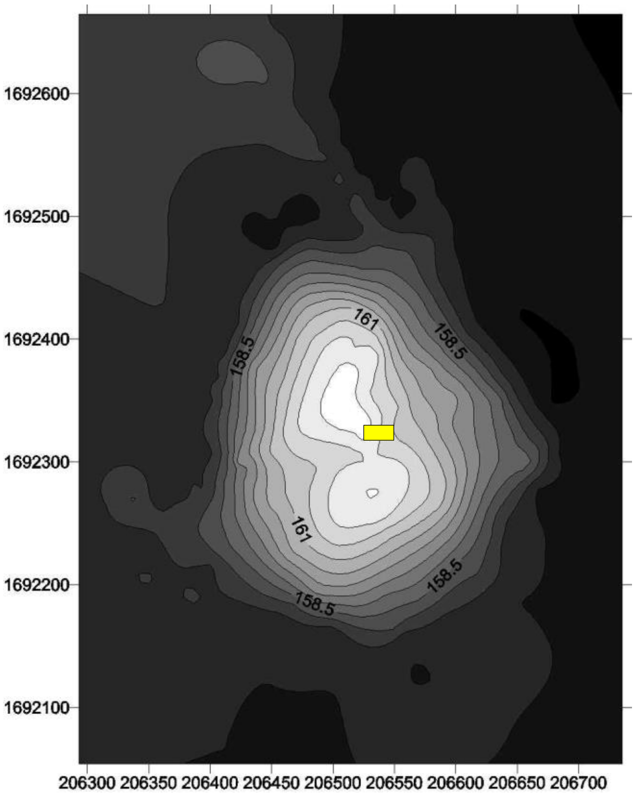


Figure 22: The location of the two excavation units at NHR, excavated in 2010/ 2011 (yellow) (prepared by Chang, 2010).

4.1.2 Chronology and Volumes of Excavation Units

The time periods of each layer and spit of all excavation units were dated using relative dating techniques, burial chronology, and carbon dates. The relative dating techniques linked artefact technology (iron, bronze) and types (pottery) with stratigraphic layers and heights. The burial chronology established by Cawte et al. (2009) was used as a cross reference in units with burial contexts. Carbon dates were obtained of six carbonised rice grains from two contexts (Appendix P), and 13 carbon dates from thirteen contexts in Kanthilatha et al. (2014). The volume of soil of each time period was calculated using the heights taken from excavation plans, averaged across the unit, multiplied the dimensions of the unit (Table 3). The 1x1 meter test pit unit N300 was excluded from this analysis as it was excavated as a bulk unit and level and spit heights were not taken.

Table 3: Layer soil volumes (m^3) for the time periods of the excavation units

Units	Layer:Spit	Height Below Datum (m)	Sediment Volume (m^3)	Wet Sieve Sample Volume (m^3)	Time Period	Dating Method
BNW						
O300	Surface – 1:3	2.925 – 3.041	1.856	0.075	Modern	
	1:4 – 1:5	3.041 (top) – 3.161	1.92	0.05	Historic	In-situ historic ceramics
	2:1 – 5:4	3.161 (top) – 4.331	18.72	0.35	Iron Age	Iron Age pottery sherds in layer 2-4
	5:5 – 7:6	4.331 (top) – 4.869	8.608	0.375	Bronze Age	Lenses of Bronze Age red sandy gravel, layer 6 similar to S400
P300	Surface – 1:3	2.551 – 2.859	4.928	0.075	Modern	
	1:4 – 1:5	2.859 (top) – 3.014	2.48	0.05	Historic	In-situ historic ceramics
	2:1 – 5:4	3.014 (top) – 4.178	18.624	0.35	Iron Age	3:5 radiocarbon date 1919 ± 32 Years cal. BP (Kanthilatha et al., 2014) 5:2 radiocarbon date 2398 ± 49 Years cal. BP (Kanthilatha et al., 2014) 2:3 jar burial Iron Age
	5:5 – 7:6	4.178 (top) – 4.938	12.16	0.375	Bronze Age	Lenses of Bronze Age red sandy gravel, layer 6 similar to S400
S400	Surface – 1:1	1.128 – 1.325	3.152	0.025	Modern	

	2:1 – 2:3	1.325 (top) – 2.167	13.472	0.075	Historic	In-situ historic material
	2:4 – 3:5	2.167 (top) – 3.37	19.248	0.35	Iron Age	2:6 radiocarbon date 1627 ± 52 Years cal. BP (Kanthilatha et al., 2014)
	3:6 – 6:3	3.37 (top) – 4.335	15.44	0.275	Bronze Age	6:2 burial 672 Bronze Age 2 Lenses of Bronze Age red sandy gravel, layer 4 similar to O,P300
G104	Surface – 1:3	1.071 – 1.331	4.16	0.075	Modern	
	1:4	1.331 (top) – 1.451	1.92	0.025	Historic	In-situ historic ceramics
	1:5 – 2:4	1.451 (top) – 2.226	12.4	0.175	Iron Age	1:5 burial 637 Iron Age 2 2:3 burial 640 & 641 Iron Age 2:4 burial 645, 646 & 647 Iron Age
	2:5 – 4:6	2.226 (top) – 3.252	16.416	0.275	Bronze Age	2:5 radiocarbon date 2600 ± 30 Years cal. BP (Kanthilatha et al., 2014) 4:4 burial 672 Bronze Age 1 4:6 burial 673 Bronze Age 1
	5:1 – 7:1	3.252 (top) – 4.033	12.496	0.125	Neolithic	6:1 radiocarbon date 3693 ± 41 Years cal. BP (Kanthilatha et al., 2014) Neolithic shell and pottery midden layer 5
N96	Surface – 1:2	0.373 – 0.453	1.28	0.05	Modern	

	1:3	0.453 (top) – 0.544	1.456	0.025	Historic	In-situ historic ceramics
	1:4 – 4:2	0.544 (top) – 1.92	22.016	0.35	Iron Age	1:6 radiocarbon date 1627 ± 52 Years cal. BP (Kanthilatha et al., 2014) 1:7 burial 683 Iron Age 2:2 burial 682 Iron Age 2:3 burial 684 Iron Age 3:1 radiocarbon date 1728 ± 25 Years cal. BP (Appendix P)
	4:3 – 6:11	1.92 (top) – 4.585	42.64	0.575	Bronze Age	4:4 radiocarbon date 2637 ± 88 Years cal. BP (Kanthilatha et al., 2014) 4:9 burial 685 Bronze Age 5 6:7 burial 688, 689, 690 & 691 Bronze Age 2/3 6:8 burial 682 & 696 Bronze Age 2/3 6:8 burial 695 Bronze Age 2 6:9 burial 697 Bronze Age 2
N100	Surface – 1:5	0.491 – 0.853	5.792	0.125	Modern	
	1:6	0.853 (top) – 0.966	1.808	0.025	Historic	In-situ historic ceramics
	2:1 – 2:7	0.966 (top) – 1.788	13.152	0.175	Iron Age	2:5 radiocarbon date 2215 ± 73 Years cal. BP (Kanthilatha et al., 2014)

						2:3 burial 637 Iron Age 2
	3:1 – 7:3	1.788 (top) – 4.1	36.992	0.525	Bronze Age	3:4 radiocarbon date 2637 ± 73 Years cal. BP (Kanthilatha et al., 2014) 4:1 burial 642 Bronze Age 5 5:1 burial 648 & 649 Bronze Age 4/5 5:2 burial 653, 654 & 655 Bronze Age 4/5 6:1 burial 658 & 659 Bronze Age 3/4 6:2 burial 660 Bronze Age 3 6:4 burial 662 Bronze Age 3/2 7:1 burial 661 Bronze Age 3/2 7:1 burial 667 Bronze Age 2
	8:1 – 10:2	4.1 (top) – 4.907	12.912	0.275	Neolithic	Neolithic pottery sherds in layer 8
I500	Surface – 1:4	2.221 – 2.948	5.816	0.1	Modern	
	2:1	2.948 (top) – 3.025	0.616	0.025	Historic	In-situ historic ceramics
	2:2 – 3:13	3.025 (top) – 4.863	14.704	0.525	Iron Age	3:11 burial 693 Iron Age 3:13 burial 699 Iron Age
	4:1 – 4:4	4.863 (top) – 5.467	4.832	0.1	Bronze Age	Bronze Age radiocarbon date layer 4 (K500)
J500	Surface – 1:4	2.491 – 3.093	4.816	0.1	Modern	

	2:1	3.093 (top) – 3.18	0.696	0.025	Historic	In-situ historic ceramics
	2:2 – 3:13	3.18 (top) – 5.095	15.32	0.525	Iron Age	Iron Age burials layer 3 (J500)
	4:1 – 4:4	5.095 (top) – 5.533	3.504	0.1	Bronze Age	Bronze Age radiocarbon date layer 4 (K500)
K500	Surface – 1:6	2.662 – 3.304	10.272	0.15	Modern	
	2:1	3.304 (top) – 3.39	1.376	0.025	Historic	In-situ historic ceramics
	2:2 – 3:13	3.39 (top) – 5.029	26.224	0.525	Iron Age	3:13 burial 694 Iron Age 1/Bronze Age 5
	4:1 – 4:5	5.029 (top) – 5.511	7.712	0.125	Bronze Age	4:3 radiocarbon date 2542 ± 25 Years cal. BP (Appendix P)
T200	Surface – 1:5	1.621 – 2.035	6.624	0.125	Modern	
	2:1 – 2:2	2.035 (top) – 2.094	0.944	0.05	Historic	In-situ historic ceramics
	2:3 – 5:6	2.094 (top) – 3.763	26.704	0.425	Iron Age	Iron Age pottery sherds in layer 2-5
						Iron Age burials layer 3 (U500)
	6:1 – 6:3	3.763 (top) – 4.457	11.104	0.075	Bronze Age	6:1 burial 664 Bronze Age 5
						6:2 burial 663, 665 & 666 Bronze Age 5
	7:1 – 8:2	4.457 (top) – 4.702	9.94	0.65	Neolithic	7:2 flexed burial 680 Neolithic
TU199-200	Surface – 1:2	1.69 – 1.888	2.376	0.05	Modern	
	2:1 – 2:2	1.888 (top) – 2.212	3.888	0.05	Historic	In-situ historic ceramics
	2:3 – 5:6	2.212 (top) – 3.859	19.764	0.425	Iron Age	Iron Age burials layer 3 (U500)

	6:1 – 6:3	3.859 (top) – 4.425	6.792	0.075	Bronze Age	Bronze Age burials layer 6 (T200)
	7:1 – 8:2	4.425 (top) – 4.681	3.072	0.65	Neolithic	7:4 flexed burial 681 Neolithic
U200	Surface – 1:4	1.694 – 2.076	4.584	0.1	Modern	
	2:1 – 2:2	2.076 (top) – 2.209	1.596	0.05	Historic	In-situ historic ceramics
	2:3 – 5:6	2.209 (top) – 3.965	21.072	0.425	Iron Age	3:6 burial 670 Iron Age
						Iron Age dog burial layer 3
	6:1 – 6:3	3.965 (top) – 4.358	4.716	0.075	Bronze Age	Bronze Age burials layer 6 (T200)
	7:1 – 8:2	4.358 (top) – 4.739	4.572	0.65	Neolithic	Neolithic burials layer 7 (TU199-200 & T200)
V200	Surface – 1:3	1.908 – 2.407	6.832	0.075	Modern	
	2:1 – 2:2	2.407 (top) – 2.579	2.752	0.05	Historic	In-situ historic ceramics
	2:3 – 5:5	2.579 (top) – 4.075	23.936	0.4	Iron Age	4:6 radiocarbon date 2195 ± 63 Years cal. BP (Kanthilatha et al., 2014)
						Iron Age burials layer 3 (U500)
	6:1 – 6:2	4.075 (top) – 4.43	5.68	0.05	Bronze Age	Bronze Age burials layer 6 (T200)
	7:1 – 7:6	4.43 (top) – 4.919	7.824	0.15	Neolithic	Neolithic burials layer 7 (TU199-200 & T200)
W200	Surface – 1:3	2.075 – 2.402	2.616	0.075	Modern	
	2:1 – 2:2	2.402 (top) – 2.519	0.936	0.05	Historic	In-situ historic ceramics

	2:3 – 5:5	2.519 (top) – 4.126	12.856	0.4	Iron Age	Iron Age burials layer 3 (U500)
	6:1 – 6:2	4.126 (top) – 4.471	2.76	0.05	Bronze Age	Bronze Age burials layer 6 (T200)
	7:1 – 7:6	4.471 (top) – 4.924	3.624	0.15	Neolithic	Neolithic burials layer 7 (TU199-200 & T200)
Z201	Surface – 1:3	2.414 – 2.84	6.816	0.075	Modern	
	1:4 – 1:5	2.84 (top) – 3.044	3.264	0.05	Historic	In-situ historic ceramics
	2:1 – 6:1	3.044 (top) – 5.077	32.528	0.5	Iron Age	Iron Age pot layer 2
BSL						
M100	Surface – 1:3	1.465 – 1.813	5.568	0.03	Modern	
	1:4 – 1:6	1.813 (top) – 2.084	4.336	0.03	Historic	In-situ historic ceramics
	2:1 – 8:5	1.813 (top) – 4.44	42.032	0.25	Iron Age	Iron Age pot layer 2
						7:2 burial B1 Iron Age
NHR						
NHR H100	Surface – 1:3	162.607 – 162.221	6.176	0.03	Modern	
	1:4 – 2:2	162.221 (top) – 161.187	16.544	0.07	Historic	In-situ historic ceramics

	2:3 – 4:2	161.187 (top) – 158.482	26.072	0.21	Iron Age	3:9 radiocarbon date 2539 ± 125 Years cal. BP (Kanthilatha et al., 2014) 3:10 radiocarbon date 2272 ± 65 Years cal. BP (Kanthilatha et al., 2014) 3:10 radiocarbon date 2465 ± 35 Years cal. BP (Kanthilatha et al., 2014)
I100	Surface – 1:3	162.446 – 162.156	4.64	0.03	Modern	
	1:4 – 2:2	162.156 (top) – 161.135	16.336	0.07	Historic	In-situ historic ceramics
	2:3 – 4:2	161.135 (top) – 158.483	27.108	0.21	Iron Age	3:9 radiocarbon date 2539 ± 125 Years cal. BP (Kanthilatha et al., 2014) 3:10 radiocarbon date 2272 ± 65 Years cal. BP (Kanthilatha et al., 2014) 3:10 radiocarbon date 2465 ± 35 Years cal. BP (Kanthilatha et al., 2014)

4.1.3 Screening Methods

All the excavations and screening methods were completed prior to the start of the PhD thesis. During the excavations of the three sites, large bones were all hand collected and all sediment was dry sieved with a ten-millimetre mesh sieve. This included sediments from all spits, features, and burial contexts of each excavation unit. The sediment and material from the 1x1 meter test pit unit N300 was excluded from all analyses, as it was excavated as a bulk unit and level and spit heights were not taken. At BNW a smaller five bucket sample (0.025m^3 of soil) from each spit was wet sieved through a two millimetre mesh, after the excavations were complete. Additional wet sieve samples were taken from feature and burial contexts, although the size of this sample varied due to the different amount of soil from each context. BNW was the only site subject to a complete systematic sampling process, including dry-sieving of all contexts and wet sieving a sample of all representative contexts.

At NHR and BSL sampling included dry-sieving of all contexts, with small fish, bird, and mammal bones recovered during the flotation for archaeobotanical samples (0.01m^3 of soil) by Dr. Cristina Castillo. Additionally, not all soil contexts were used during the flotation process, this reduced the sample size of small bone elements from NHR and BSL and limited any direct quantitative comparison between the three sites. Care was taken to consider these sampling differences when comparing the animal distributions at all three sites in the discussion. All materials, including artefacts and animal bones, were cleaned (if possible) and stored with their context information. The faunal material recovered directly from excavation, as well as from the screening methods, formed the collection for this thesis.

4.2 TAXONOMIC CLASSIFICATION OF ANIMAL BONES

The identification of faunal material was done post-excavation in a research facility, in the town of Phimai, Nakhon Ratchasima, Thailand. Due to the large quantity of animal bones recovered during excavation, the identification was undertaken by a team including; Dr. Rachanie Thosarat, Chanakarn Hongthong, and Gordon Stenhouse. Permission to use the data in this PhD thesis was granted by all members of the team. Dr. Rachanie Thosarat's comparative collection was used as a reference to classify the animal bones into their taxonomic ranks of Class, Order, Family, Genus, and Species. All identifiable bone elements were classified to the lowest level possible, preferably to Species. Each specimen was individually identified by all members of the team. If the taxonomic rank was uncertain the bone element was classified in a higher rank, for example if the Genus was unclear it was classified to Family.

As there was only one specimen of deer (*Muntiacus muntjak*) in the comparative collection, all deer bones were compared to this specimen and then placed in a size group. The groups are based on the size of the shoulder height (SH) of living deer (SH from: Francis, 2008, pp. 128-132). The larger bone elements were classified as sambar deer (*Rusa unicolor*, SH 1,400-1,600), the medium elements as Eld's deer or Schomburgk's deer (*Rucervus eldii*, SH 1,200-1,300, and *Rucervus schomburgki*, SH 1,050), the small elements as hog deer or muntjac deer (*Axis porcinus*, SH 650-720 and *Muntiacus muntjak* SH 500-550), and the very small elements as mouse deer (*Tragulus spp.*, SH 200-350). If the element was fragmented or fell between the size categories of the groups, it was classified to the family level of Cervidae. Antler was not classified using size groups, as they are morphologically identifiable to species level only if the base, fork, or whole antler is present (Figure 23). If the antler was too fragmented, or just the crown remained, the element was the classified to the family level.

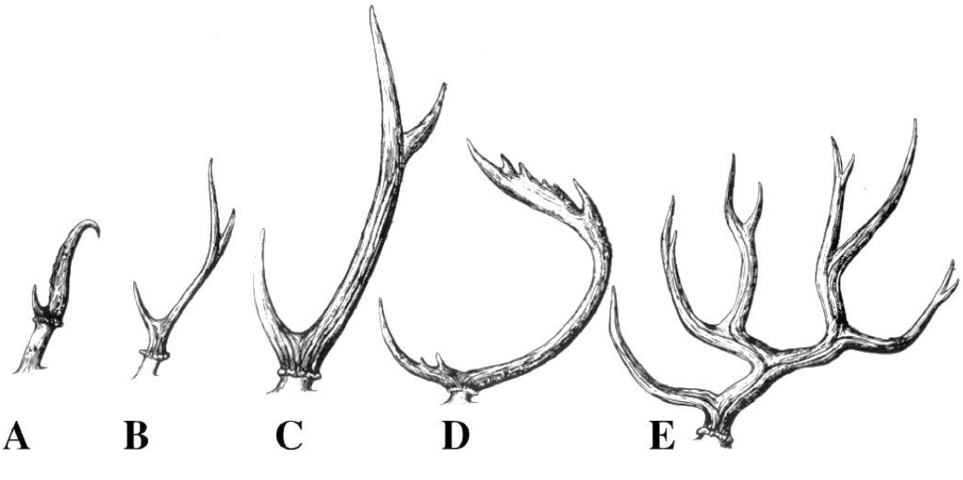


Figure 23: The antler types of the Thai deer species. From the left (A) *Muntiacus muntjak*, (B) *Axis porcinus*, (C) *Rusa unicolor*, (D) *Rucervus eldii*, (E) *Rucervus schomburgki* (From: Lekagul & McNeely, 1977)

Three of the four familiae of turtles and tortoises were grouped together, due to general fragmentation of the carapace and plastron. Box, pond, and water turtle (Geoemydidae), big-headed turtle (Platysternidae), and tortoise (Testudinida) were grouped into a single category. However the family of soft-shelled turtles (Trionychidae) was separated, as it is easily distinguished from the other three turtle and tortoise familiae due to the rough surface of its carapace and plastron. Nutaphand's *Turtles of Thailand* (1979) was used to aid in the identification of smaller bone elements, other than the carapace and plastron.

The class title of mammalia (small) was used to group together small mammals. Four familiae of the mammalia (small) class title were identifiable as they had representative samples in the comparative collection. These were mice and rats (Muridae), hare (Leporidae), pangolin (Manidae), and mongoose (Herpestidae). Other familiae within the mammalia (small) class title that could not be identified to family level included; moonrats and moles (Erinaceidae), shrews (Soricidae), treeshrews (Tupaiidae), pen-tailed treeshrews (Ptilocercidae), martens, badgers and weasels (Mustelidae), civets and binturongs (Viverridae), linsangs (Prionodontidae), squirrels (Sciuridae), bamboo rats (Spalacidae), and porcupines (Hystricidae).

Birds were classified under the class title Aves. The small elements were most likely to be from the order of perching birds (Passeriformes) or parrots (Psittaciformes), and the larger bird bone elements from further orders. Due to a lack of comparative specimens these bones were not classified further than their class level. However, chicken/ red junglefowl (*Gallus gallus*) was identified to species level with the aid of samples in the comparative collection.

The majority of faunal material from the class of ray-finned fishes (Actinopterygii) was collected from the wet sieve sample. The method and materials used to identify the bone elements and classify them into their taxon is outlined in Thosarat (2004, pp. 171-180). Thosarat obtained fish from markets in Phimai, northeast Thailand and Siem Reap, Cambodia, to be used as a comparative sample to identify the prehistoric remains recovered from excavation. Voeun (2006) was also used to aid in the identification process. Similarities in some elements meant that not all the bone elements could be classified to species level, with many only classified to the level of genus or family.

4.3 BIOMETRY AND MORPHOLOGY USED FOR CLASSIFICATION

After the initial visual classification, calliper measurements of bone elements from the excavation units and the comparative collection were used to aid in further refining the identification of animal remains. Only specific bone elements were measured, as not all bone elements are useful in narrowing down animal classification, due to morphological similarity between some species or genera.

4.3.1 Bovidae

To distinguish between the two genera of bovines, water buffalo (*Bubulus*) and cattle (*Bos*), measurements of metacarpals, metatarsals, magnums, and the first fore and hind phalanges of adult bovine were taken (Figure 25, Figure 26, Figure 29, Figure 31). This followed the method of Higham (1975), and Kijngam (2010, p. 190). As Higham (1975) noted, the ratio of length, proximal end width, and distal end width of metacarpals and metatarsals differs between the two genera of bovines. The distal end width of the *Bubulus* metacarpal is wider than its proximal width, whereas the distal end width of the *Bos* metacarpal is much closer to the proximal width (Figure 24). The metatarsals display a similar trend, with the *Bubulus* distal width wider than its proximal width, when compared with the *Bos* metatarsal. Therefore, measurements were taken of these aspects. The minimum width of the metacarpals and metatarsals were also measured. The differences in the morphology of the proximal articular surface of the metacarpals and metatarsals were noted, as they are also diagnostic (Figure 27). The groove between the two facets on the proximal articular surface of the metacarpal is more pronounced in *Bubulus* than in that of *Bos*. The ridge between the two facets is therefore shorter on the *Bubulus* metacarpal. The proximal articular surface of the metatarsal has four facets with a grove in the central area. The groove has an irregular shape in the *Bos* when compared to the *Bubulus* metatarsal. Due to the irregular shape of the groove, the lateral and medial facets of *Bos* are more asymmetrical than that of *Bubulus*. The smaller facets on the caudal side are longer in *Bubulus* then *Bos*, and extend to the medial side of the bone.

The magnum (fused 2nd and 3rd carpal) of the bovine was measured as they are morphologically different between the two genera. The maximum width of the *Bubalus* magnum is shorter than its maximum depth, and in the *Bos* magnum this is reversed, with the maximum width longer than the maximum depth (Figure 28). The length of the magnum was measured and the absence or presence of a triangular shaped indent on the distal articular surface was noted.

Figure 24: The cranial view of the right metacarpal and right metatarsal of *Bubalus bubalis* and *Bos taurus*. From the top; metacarpal of *Bubalus bubalis*, metacarpal of *Bos taurus*, metatarsal of *Bubalus bubalis*, metatarsal of *Bos taurus*.

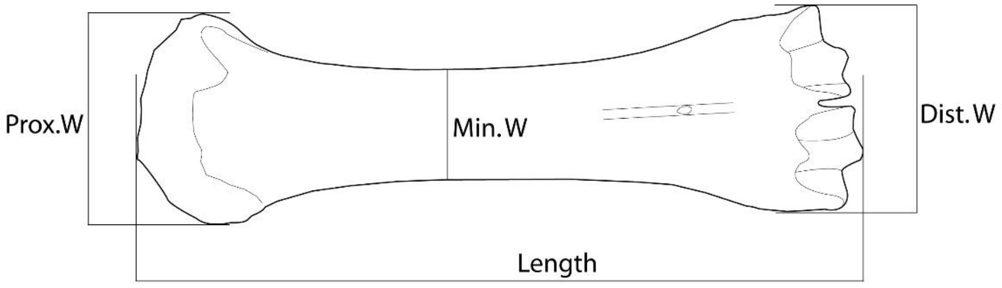


Figure 25: The measurements taken for bovine metacarpal

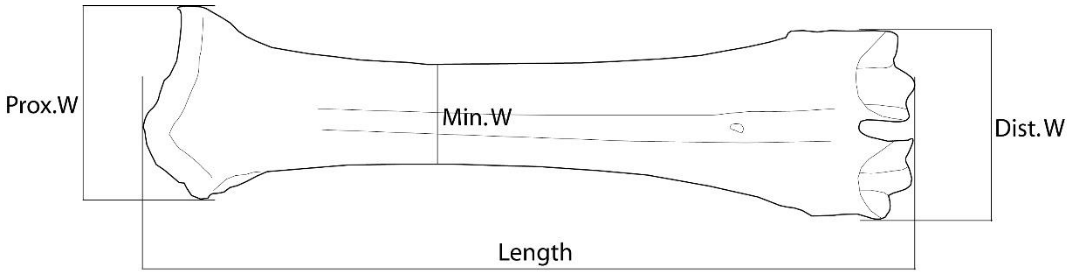


Figure 26: The measurements taken for bovine metatarsals

Figure 27: The proximal articular surface of the right metacarpal (top row) and right metatarsal (bottom row) of *Bubalus bubalis* (left column) and *Bos taurus* (right column)

Figure 28: The proximal view (top row) and distal view (bottom row) of the right magnums of *Bubalus bubalis* (left column) and *Bos taurus* (right column)

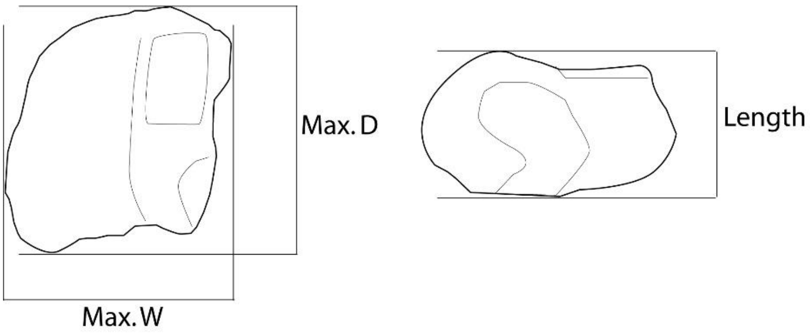


Figure 29: The measurements taken for bovine magnums, proximal view (left) and lateral view (right)

The proximal end width and length of the first fore and hind phalanges were also measured, as were the distal end width and minimum width of the first fore and hind phalanges (Figure 31). The distal end width of the first phalanges of the *Bubulus* is wider when compared to the proximal end of *Bos javanicus* and *Bos Taurus*. However *Bos gaurus* first phalanges dimensions overlap *Bubulus*, with regard to distal end width (Higham, 1975). Other morphological differences were also considered to narrow down the genus. The presence of a smooth or irregular ridge on the posterior distal articular surface was also recorded. The ridge is smooth in *Bubulus* first phalanges and irregular on *Bos*, including *Bos gaurus* (Figure 30). The third phalanx is an additional bone that was used to distinguish between the two genera of bovines. This element was classified during the initial visual classification and not measured, as it was easily identified by eye with the aid of the comparative collection (Figure 32).

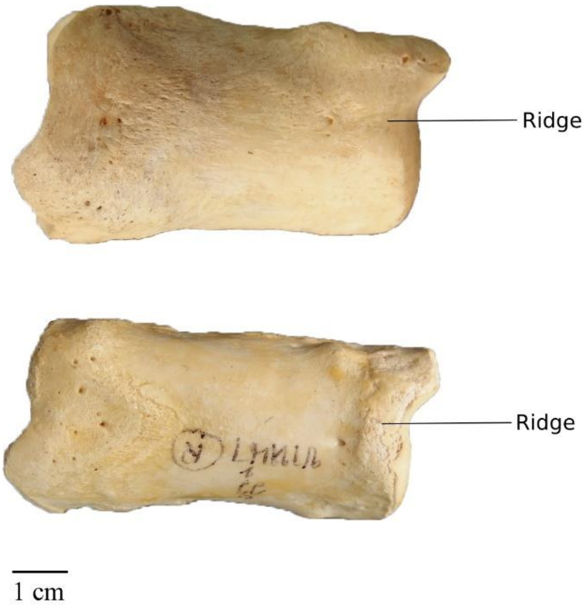


Figure 30: The cranial view of the right first fore phalanx *Bubalus bubalis* (top) and *Bos taurus* (bottom)

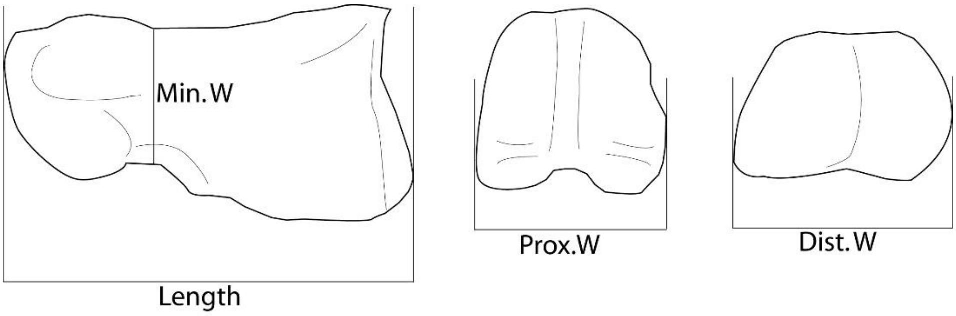


Figure 31: The measurements taken for bovine first fore and hind phalanges, lateral view (right), proximal view (medial) and distal view (right)

Figure 32: The abbatial view of the right third fore phalanx (top row) and right third hind phalanx (bottom row) of *Bubalus bubalis* (left column) and *Bos taurus* (right column)

The permanent second lower premolar was also used to distinguish between the two genera of bovines. The *Bos* second lower premolar in length and depth is reduced in size and has a lower crown in comparison to the *Bubalus* tooth (Higham, 1975) (Figure 33). This element was classified during the initial visual classification and not measured, as it was easily identified by eye with the aid of the comparative collection.

Figure 33: The second lower premolar of *Bubalus bubalis* (left) and *Bos taurus* (right)

The metacarpals and metatarsals from the medium sized bovines, goat-antelopes subfamily (Caprinae), were also measured to classify the element into one of the two genera, serows (*Capricornis*) or gorals (*Naemorhedus*). The length and the distal end width of the metacarpal was measured and compared with the length and the distal end width range of other members of the Caprinae subfamily, recorded in Mead and Taylor (2005). The proximal end width and minimum width were also recorded at this stage.

4.3.2 Muridae

To help narrow down the classification of the mice and rats family (Muridae) into the eight genera found in northeast Thailand (*Rattus*, *Bandicota*, *Berylmys*, *Niviventer*, *Leopoldamys*, *Maxomys*, *Mus*, and *Vandeleuria*), measurements of the lower molars (M_1-M_3) and upper molars (M^1-M^3) were taken (Figure 34). Depending on the intactness of the mandible samples, additional measurements were taken (Figure 34, Table 4). The measurements were compared with comparative samples of *Bandicota indica* and *Bandicota savilei* obtained from the markets in Phimai in northeast Thailand. The lesser bandicoot rat *Bandicota bengalensis* was not used in the sample as its present day geographic range is outside of northeast Thailand. The other seven genera were compared to measurements recorded in the literature (Table 4) (Dhaliwal, 1962; Francis, 2008; Maryanto, 2003; Musser & Brothers, 1994; Musser & Newcomb, 1985). To rule out members of some genera, such as the *Vandeleuria* genera, the cusp morphology of the teeth was compared to Heaney et al. (2009).

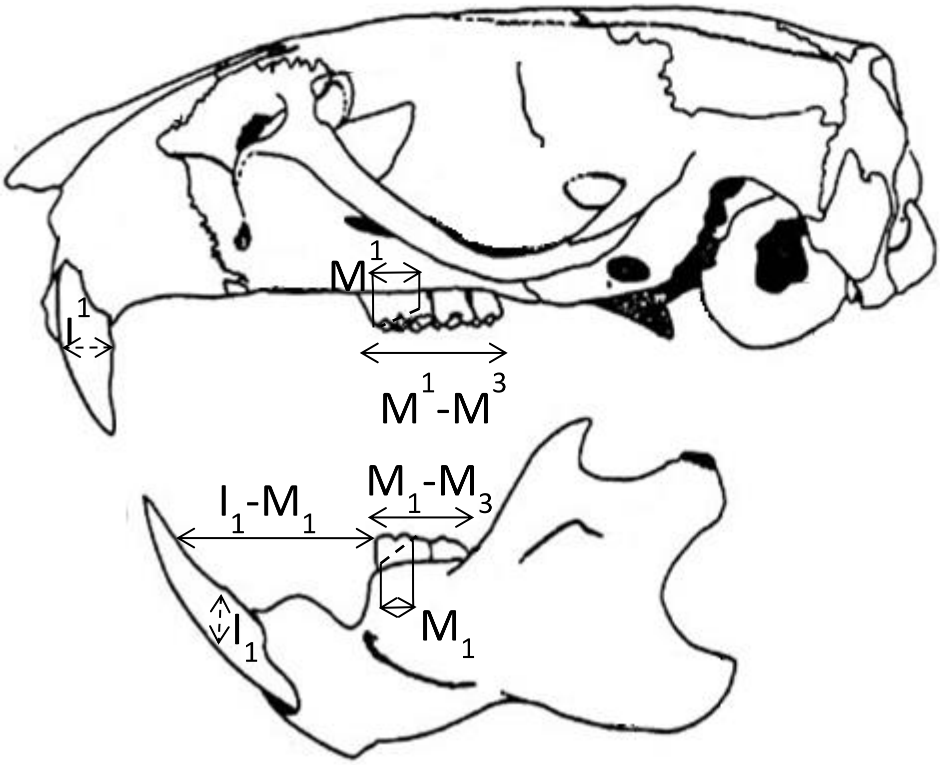


Figure 34: Measurements taken of the Muridae maxilla and mandible

Table 4: The present day maxilla and mandible measurements of Muridae in northeast Thailand (After: Dhaliwal, 1962; Francis, 2008; Maryanto, 2003; Musser & Newcomb, 1985)

Taxon	M^1-M^3 L	M_1-M_3 L	I_1-M_1 L	I_1 D	M_1 D	I^1 D	M^1 D
Rattus rattus	6.2-7.0	-	-	<2	-	<2	-
Rattus exulans	4.6-5.5	4.5-4.9	-	<2	-	<2	-
Rattus losea	-	6.2-6.7	-	<2	-	<2	-
Rattus norvegicus	7.3-8.4		-	<2	-	<2	-
Rattus tanezumi	6.5-7.6	6.0-7.2	-	<2	2.0-2.3	<2	-
Bandicota indica	10.2-12.4	10.7-12.4	-	>2	-	>2	-
Bandicota indica ♀*	11.04	10.7	10.06	2.82	2.68	2.76	3.33
Bandicota savilei	8.6-9.7	8.6-9.7	-	>2	-	>2	-
Bandicota savilei ♂*	8.66	9.08	9.13	2.31	2.58	2.1	2.87
Berylmys berdmorei	6.6-7.8	7.2-8.0	-	<2	2.2-2.4	<2	-
Niviventer fulvescens	5.7-6.6	5.8-6.3	-	<2	1.6-1.9	<2	-
Leopoldamys sabanus	8.7-11.8	8.8-10.1	-	<2	2.5-3.1	<2	-
Maxomys surifer	5.9-7.5	6.1-6.9	-	<2	2.0-2.2	<2	-
Mus musculus	3.3-3.7	3.3-3.7	-	<2	-	<2	-
Mus caroli	3.1-3.5	3.2-3.8	-	<2	-	<2	-
Mus cervicolor	3.2-3.9	3.4-4.0	-	<2	1.2-1.3	<2	-
Vandeleuria oleracea	-	-	-	<2	-	<2	-

* Comparative samples from the markets in Phimai in northeast Thailand

4.3.3 Canidae

The mandibles of the Canidae family were measured in order to distinguish between the golden jackal *Canis aureus* and the domestic dog *Canis familiaris*. The measurements were then compared to Higham et al.'s (1980) average length and breadth data for the golden jackal from modern and archaeological examples. To separate between the genera *Canis* and *Cuon* (which has one representative - the dhole *Cuon alpinus*) the presence of the lower M_3 was noted. The paired cusps on the talonid, caudal end of the lower M_1 was also noted. The lower M_3 and the paired cusps on M_1 are present only in the *Canis* genera (Piper et al., 2014).

4.4 AGE AT DEATH ESTIMATES

The age at death estimates for pig were based on tooth eruption and wear. This taxon was selected based on their overall abundance in the assemblage. Only mandibles with teeth present were used in the age at death estimates. Whether the tooth was deciduous or permanent and the extent of the crown development stage (CDS) were recorded (Table 5). An evaluation of the tooth wear stage on the lower deciduous premolar 4 (dp_4), lower permanent premolar molar 4 (P_4), and the lower permanent molars (M_1, M_2, M_3) was carried out, following the methods outlined in Grant (1982). These methods categorise the tooth wear stage (TWS) based on the erosion of the outer layer of light coloured enamel, to the darker coloured dentine below (Grant, 1982, p. 92) (Figure 35). The dp_4, P_4, M_1, M_2, M_3, if present, were given a CDS or TWS. In Grant (1982, p. 92) the CDS and the TWS for pig teeth were numbered (C=1–n=18). The numerical vales for the whole molar row were then added together to give an age at death estimate. This method was modified due to the fragmentation of the archaeological mandible samples, which more often than not lacked the whole molar row. The age at death estimate was obtained by using the CDS and the TWS, and by classifying results into the age stage of tooth eruption, and the wear on the teeth that occurs during the life of the animal (Bull & Payne, 1982; Grant, 1982; Xiaolin, 2004) (Table 6). The use of age class or stages has also been used by Hayashi et al. (1977) and recently utilised by Hongo and Meadow (2000) and Sawada et al. (2011).

Table 5: Tooth crown development stage used for age at death estimates

Notation	Crown Development Stage
C	Perforation in crypt visible
V	Tooth visible in crypt but below head of bone
E	Tooth erupting through bone
1/2	Tooth half erupted
U	Tooth almost at full height but unworn
*D	Damaged
^S	Shed

From: Grant, 1982; ^ Lemoine et al., 2014; * Piper et al., 2014

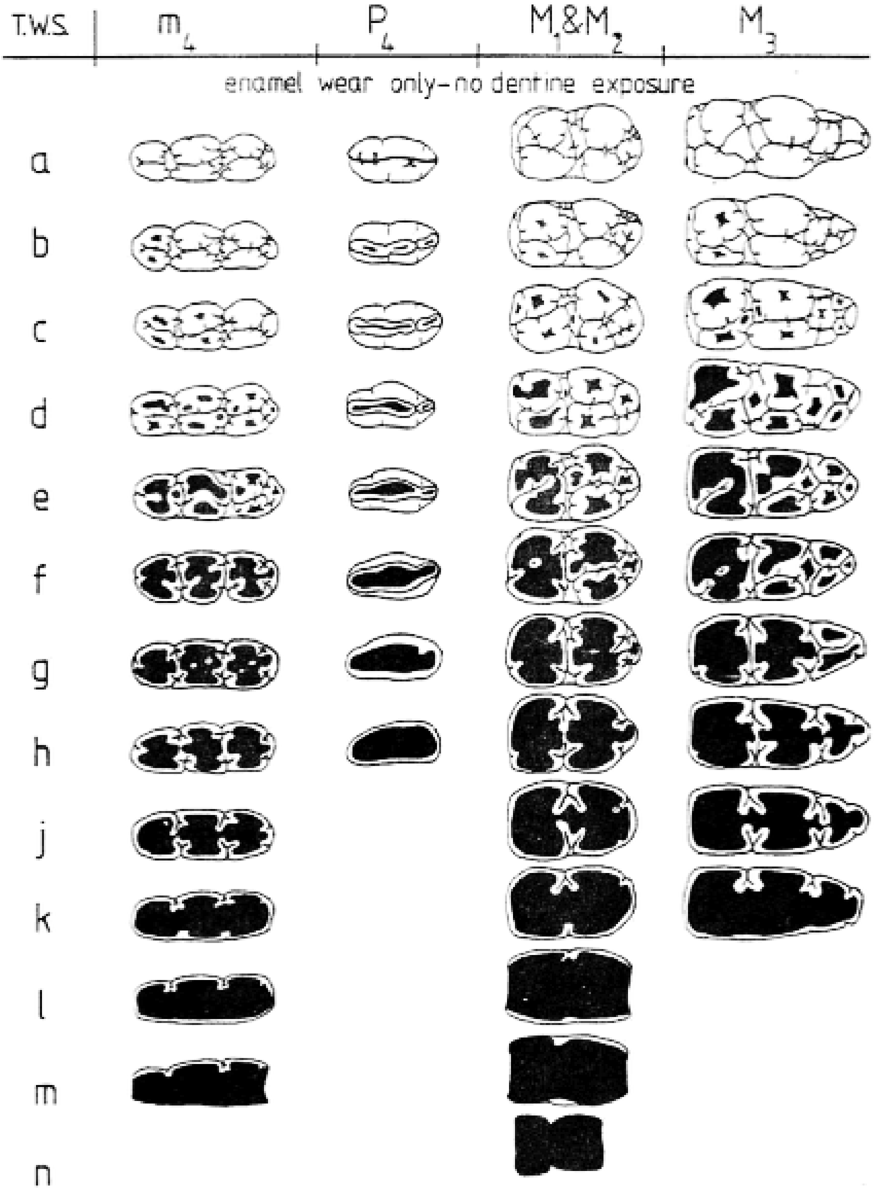


Figure 35: Mandible tooth wear stages (TWS) for pig (From: Grant, 1982, p. 92)

Table 6: Age class, eruption, and wear stages for *Sus* teeth

Age class	Age Stage	Tooth	Tooth wear stage
I	**Newborn** (ca. less than 4 months)	dp_4	a, b, c
II	**Infantile**	dp_4	d, e
	(ca. 4 to 6 months)	M_1	erupting, a
III	**Juvenile**	dp_4	f, g, h, j, k, l, m
	(ca. 6 to 12 months)	M_1	b, c
		M_2	erupting
IV	**Young sub-adult**	P_4	erupting, a, b, c
	(ca. 12 to 18 months)	M_1	d, e
		M_2	a, b, c
V	**Sub-adult**	P_4	d, e
	(ca. 18 to 24 months)	M_1	f, g, h
		M_2	d, e, f
		M_3	erupting, a, b
VI	**Adult**	P_4	f
	(ca. 24 to 36 months)	M_1	j, k
		M_2	g, h
		M_3	c, d, e
VII	**Old Adult**	P_4	g, h
	(ca. over 36 months)	M_1	l, m, n
		M_2	j, k, l, m, n
		M_3	f, g, h, j, k

Eruption and wear stages after: Bull & Payne, 1982; Grant, 1982; Xiaolin, 2004

One pig mandible sample from the comparative collection was recovered from a domestic pig at the modern village of BNW (Figure 36). The age of this pig was recorded to be twenty-four months old. The right and left mandibles were tested against Grant's (1982, p. 92) method, and the age class, eruption, and wear stage methods used in this thesis. The value for the left and right mandibles using Grant's (1982, p. 92) method was twenty-five months old (c=8 + c=8 + b=7 + V=2 = 25). Using the age class method the left and right mandible classified as age class V Sub-adult (ca. 18 to 24 months). However, the P_4 was in the age class IV Young sub-adult (ca. 12 to 18 months). It is worth noting the age of death is an estimate, and many factors such as localised weather, the species or sub-species, and the hardness of food consumed would all affect the results.

Figure 36: A twenty-four month old right pig mandible from the comparative collection

The state of epiphyseal fusion was also noted during the classification stage for all taxonomic ranks. Three categories were used; unfused, partially fused, and fused. Epiphyseal fusion was not used in the age at death estimates. However, this was used for the Minimum Number of Individuals (MNI) estimate, which is discussed below in *4.5.2 Estimating the Minimum Number of Individuals*.

4.5 QUANTIFICATION TECHNIQUES

During the identification and classification of the faunal remains all information, including: site information, taxon, bone element, element side of the body, bone fragment location, measurements, and photos, were entered into an excel spreadsheet. Following the identification and classification of the faunal remains, data was quantified into Number of Identified Specimens (NISP) and Minimum Number of Individuals (MNI). The NISP is the total count of bone elements that are present in a taxonomic rank. The MNI is an estimate of how many individuals of a taxonomic rank could have been represented by the bone element, within an assemblage. It should be noted that NISP and MNI are not an estimate of past population sizes of individual taxon, as anthropogenic factors and taphonomic processes, including excavation method, can influence these counts considerably.

4.5.1 Number of Identified Specimens

Number of Individual Specimens (NISP) is the total count of bone elements that are present in a taxonomic rank. The data in this thesis is examined by site, and the NISP count is the primary score of data presented in graphs and tables in *Chapter 5: Results* of this thesis. This is in line with a shift in recent research within the Southeast Asian region, from MNI counts, which were popular during the twentieth century, towards NISP counts, which are more prevalent today (Conrad, 2015). One of the problems when considering the use of NISP data is a single skeletal element can be fragmented, thus it is then counted multiple times (Conrad et al., 2016). Similarly, MNI estimates are undercounted because arbitrary groups are used to exclude elements from the sample. The taxonomic quantity is somewhere between the MNI and the NISP values (Conrad et al., 2016; Grayson, 1984, pp. 51-52).

4.5.2 Estimating the Minimum Number of Individuals

Minimum Number of Individuals (MNI) estimates how many individuals of a taxonomic rank could have been represented by recovered bone elements. Taxonomic ranks that were separated from the higher rank Bovidae Family by only a few bones, such as the *Bos* sp. and *Bubalus* sp. Genus, were given their own MNI estimates. Thus, the *Bos* sp. and *Bubalus* sp. were not included in the Bovidae MNI estimates. The MNI estimates first grouped the bone elements into the bone type (humerus, radius, ulna, etc.), fragment location (distal end, proximal end, shaft, etc.), and the stage of epiphyseal fusion of each bone noted during the classification process. Then the side of the body (left or right) data, was entered into *Chaplin's Equation* (Chaplin, 1971):

$$\text{MNI} = \text{RIGHT} + \text{LEFT} - \text{PAIR}$$

Chaplin's Equation prevents paired bone elements from being counted twice. In cases where the side (L or R) was unclear the bone element was divided by the number of possible parts that make up a whole animal:

$$\text{MNI} = \frac{\text{NUMBER OF BONE ELEMENTS}}{\text{NUMBER OF PARTS IN WHOLE ANIMAL}}$$

To use the MNI statistic correctly results must be non-additive under the separation of contextual units (Winder, 1995). Calculating the MNI from each site context, and then adding the results together, can give an inflated numerical value, as individual animals across contexts are counted twice. The number is further inflated when arbitrary contexts, such as spits, are used. To prevent this occurring the *Grayson Inequality Equation* (Grayson, 1984) was used:

$$MNI_{total} \leq MNI_{context\ 1} + MNI_{context\ 2}$$

The *Grayson Inequality Equation* prevents individuals from across contexts from been counted twice. All the MNI are presented by excavation unit, joint excavation units were grouped together, and the *Grayson Inequality Equation* was used on the grouped units to estimate MNI.

4.5.3 Number of Identified Specimens by Volume (m^3)

The NISP by volume (m^3) was calculated using the NISP count for each taxa within a given time period divided by the volume (m^3) of sediment within the time period (Table 3). The calculation was carried out on the hand collected/ dry sieve data, wet sieve sample, and flotation sample separately. These results were calculated using the total volume of soil within a particular time period by site, not square. As such, this data provides a more general, but nevertheless important statistic to support and strengthen the overall frequency data over time at all sites. Temporal trends across sites, and between sites with difference sampling methods, can be examined through this approach (McKechnie, 2012).

4.6 ETHICAL CONSIDERATIONS

The bones used as reference materials in the comparative collection were all collected through ethical and lawful means before the commencement of this thesis. The entire comparative collection was obtained in accordance with the Wildlife Preservation and Protection Act, B.E. 2535 [1992] and the Fisheries Act, B.E. 2490 [1947] of the Kingdom of Thailand. No archaeological material or reference materials were removed from the Kingdom of Thailand for the purposes of this thesis.

Chapter 5: Results

This chapter presents the results of the faunal analysis from the three archaeological sites of BNW, BSL, and NHR. An overview of the condition of preservation and fragmentation of the faunal assemblage at all three sites is presented. The Number of Identified Specimens (NISP) and Minimum Number of Individuals (MNI) estimates for each taxon are also provided, along with the percentage of NISP within the family, order, or class level. Likewise the most commonly identified taxon and their contexts are given. The anatomical locations of identified bone elements from Bovidae, *Sus scrofa*, and Cervidae are also provided. The age at death estimates for pig are also presented.

5.1 PRESERVATION AND FRAGMENTATION OF THE ASSEMBLAGES

The excavations at sites BNW, BSL, and NHR all contained bone and other organic matter such as shell and carbonised plant remains. However, the condition of the samples from all sites differed throughout the stratigraphic sequence (Table 7). It was observed that the bones from the upper layers at all sites were white, flaked, and cracked with rounded edges and scrape marks (Figure 37). Some of these marks could have been caused by gnawing from animals. The rounded edges and scrape marks are an indication that the bones would have been moved by natural or anthropogenic forces pre-deposition. The faunal remains that were recovered from the middle and lower layers have different levels of mineral concretions adhered to the surface of the bone (Figure 38). Some of the concretions solidified post-excavation. The time between unearthing and cleaning may have caused the concretions to set hard on the bone surface.

The assemblages from all sites were highly fragmented, with only a couple of long bones from larger animals remaining fully intact. Smaller bones from larger animals, such as the carpals, tarsals and phalanges, were more often recovered intact. The faunal remains from smaller animals were also more often recovered complete, however, a number were still fragmented. The majority of the fragmentation was pre-depositional. Breakages would have occurred during the butchery process, which more than likely included the breaking of long bones for marrow extraction. Other pre-depositional factors such as trampling, scavengers, and weathering would have also caused breakages. It was observed during the excavation that some faunal remains were fragmented post-deposition, due to the weight of the soil above. In most cases these faunal remains were pieced back together once excavated. Clean breakages also occurred during excavation and washing, however these were also pieced back together during the analysis stage.

Figure 37: Condition of bones from the upper layers

Figure 38: Concretions on bones from the middle and lower layers

Table 7: The condition of the faunal remains by layer from BNW, BSL, and NHR

Site	Layer: Spit	Condition
BNW (west edge) N,O,P300, S400, G104	1:1 – 2:12	Rounded, very leached, no concretions, white in colour
	3:1 – 4:6	Not rounded, light concretions, light brown in colour
	4:1 – 4:6	Not rounded, heavy concretions, light brown in colour
	5:1 – 5:8	Not rounded, heavy concretions, dark brown in colour
	6:1 – 7:5	Not rounded, light concretions, dark brown in colour
BNW (centre) N96, N100	1:1 – 2:7	Very rounded, leached, no concretions, white in colour
	3:1 – 4:9	Not rounded, light concretions, light brown in colour
	5:1 – 6:10	Not rounded, heavy concretions, brown in colour
	7:1 – 7:3	Not rounded, light concretions, brown in colour
	8:1 – 9:3	Not rounded, light concretions, dark brown in colour
BNW (east edge) I,J,K500, TU199-200,T,U,V,W200, Z201	1:1 – 2:12	Rounded, leached, no concretions, white in colour
	3:1 – 4:8	Not rounded, light concretions, light brown in colour
	5:1 – 5:6	Not rounded, heavy concretions, light brown in colour
	6:1 – 7:3	Not rounded, light concretions, dark brown in colour
BSL	1:1 – 2:6	Very rounded, very leached, no concretions, white in colour
	2:7 – 3:2	Rounded, leached, light concretions, white in colour
	3:3 – 4:3	Not rounded, heavy concretions, light brown in colour
	5:1 – 5:5	Not rounded, light concretions, brown in colour
	6:1 – 7:1	Not rounded, light concretions, dark brown in colour
	7:2 – 8:3	Not rounded, very light concretions, dark brown in colour
NHR	1:1 – 2:5	Very rounded, very leached, no concretions, white in colour
	3:1 – 4:1	Not rounded, light concretions, light brown in colour

5.2 BAN NON WAT FAUNAL ANALYSIS

Over the four excavation seasons (2007-11) more than 60000 bone pieces were uncovered at BNW. A total of 21292 bone pieces were identified, and placed into 56 taxonomic groups (Table 8). All squares at BNW contained both wild and domestic animal species, from both terrestrial and aquatic ecosystems. The mammalian fauna included domestic dog, cats, tiger, mongoose, pigs, cattle, water buffalo, and large, medium, and small-sized deer. The measurements of pig mandibles were in the range of both wild and domestic animals (Appendix A). No jackal elements were identified from the mandible measurements of the *Canis* genus (Appendix C). However, it is likely that a small amount of the *Canis* sp. taxon includes bones from *Canis aureus,* the golden jackal. Larger mammals, such as rhinoceros and Asian elephant, were also present in the assemblage in low numbers. Small mammals included hare, bamboo rat, greater bandicoot rat, Savile's bandicoot rat, white toothed rat, white bellied rat, mouse, and true rat from the *Rattus* genus. The assemblage also contained small mammal bones, which was only able to be identified to a class level. The reptilian fauna was mainly turtle and tortoise, although soft-shelled turtle, snake, monitor lizard, and crocodile were identified in small numbers. Avian fauna was represented by chicken/ red junglefowl, although some elements were only identified to class level. Twenty taxa of fish were identified, with the snakehead murrel being the most commonly identified, followed by the walking catfish and the climbing perch. The naked catfish and the Asian swamp eel were also identified in large numbers.

5.2.1 The Frequency of Identified Taxa (NISP)

Fish from the ray-finned fish class accounted for 59 per cent of the NISP recovered. Fish from the Channidae family were the most highly represented in the assemblage, making up 22 per cent of the NISP (Figure 39). The Clariidae family of fish showed the second highest NISP, accounting for 12 per cent, closely followed by the Anabantidae family, also on 12 per cent. The Bagridae family was the next highest fish identified with six per cent of the overall NISP. The Synbranchidae and the Siluridae were the next highest NISP found, with four and two per cent respectively. The remaining Cyprinidae, Notopteridae, Pangasiidae, Nandidae, and Osphronemidae familiae all together accounted for less than one per cent of the NISP.

The pig was the highest represented mammalian fauna, accounting for 12 per cent of the overall NISP. Bovid, including water buffalo and cattle, was the next highest mammal taxon identified, with eight per cent. The ratio of identifiable elements of water buffalo to cattle was 1.1:1. Deer accounted for six per cent of NISP, closely followed by the turtle and tortoise, also with six per cent. The *Canis* genus, including the domestic dog and jackal, constituted five per cent of all NISP. The cat, rats and mice, small mammal fauna each accounted for one per cent of NISP. The frog, soft-shelled turtle, snake, monitor lizard, crocodile, bird, chicken/ red junglefowl, mongoose, rhino, Asian elephant, hare, bamboo rat, and the small mammal fauna each made up less than one per cent of NISP.

5.2.2 MNI Estimates

MNI estimates demonstrate that fish species the snakehead murrel and the climbing perch were the highest represented individuals in the assemblage. Although the Clarias fish genus was the seconded highest NISP, it was the third highest MNI estimate, with less than half the number of individuals when compared to the snakehead murrel or climbing perch. The MNI of the *Clarias* genus was closely followed by the Asian swamp eel and the naked catfish. The butter catfish, yellow catfish, and carp/ minnow MNI estimates were also comparatively high. The pig MNI estimate was the highest of the mammal fauna, with 30 young and 37 older individuals estimated. Eld's and Schomburgk's deer were the second highest mammal MNI estimates, with three young and 30 older individuals. The bovid MNI estimates consisted of six young and 21 older individuals. The water buffalo MNI estimates outnumber the cattle 12 to 10, with two young and 10 older individual water buffalos estimated. Cattle, on the other hand, had one young and nine older individuals. The mouse and rat had two young and 24 older individuals estimated. The *Canis* genus had three young and seven older individuals estimated, and domestic dog one young and nine older individuals estimated. However, one of the young domestic dogs was a whole dog burial, and likewise two of the nine older individuals were dog burials. Hog and barking deer had a MNI estimate of nine, with two young and seven older individuals. Small mammals also had a MNI of nine, with eight small and one larger individual estimated. Additionally, there were 12 frogs from the Amphibian class and seven turtles and tortoises from the Reptilia class recovered. The chicken/ red junglefowl and bird both had an MNI estimate of four, with the chicken/ red junglefowl having four older individuals and the bird three small and one larger individual.

Table 8: NISP and MNI of taxa from all hand collected, dry sieved, and wet sieved samples from all contexts at BNW

Class	Order	Family	Taxon	Common name	NISP	NISP (%)	MNI
Amphibian	Anura			Frog	56	0.26	12
Reptilia	Testudines	Geoemydidae/ Platysternidae/ Testudinidae		Box, pond and water turtle/ Big-headed turtle/ Tortoise	1320	6.20	7
		Trionychidae		Soft-shelled turtle	12	0.05	1
	Serpentes (Suborder)			Snake	13	0.06	1
	Squamata	Varanidae	*Varanus* sp(p).	Monitor Lizard	5	0.02	2
	Crocodilia	Crocodylidae		Crocodile	4	0.02	1
Aves				Bird	30	0.14	4
	Galliformes	Phasianidae	*Gallus gallus*	Chicken/ Red junglefowl	32	0.15	4
Mammalia	Carnivora	Canidae	*Canis* sp(p).	Domestic dog/ Jackal	506	2.38	10
			Canis familiaris	Domestic dog	654	3.07	10
		Felidae		Cat	241	1.13	3
			Panthera tigris	Tiger	2	0.01	1
		Herpestidae	*Herpestes* sp(p).	Mongoose	4	0.02	2
	Artiodactyla	Suidae	*Sus scrofa*	Pig/ Boar	2450	11.51	67
		Bovidae		Bovid	1388	6.52	27
			Bos sp(p).	Domestic/ Wild Cattle	129	0.61	10
			Bubalus sp(p).	Water buffalo	146	0.69	12
		Cervidae		Deer	163	0.77	2
			Rusa unicolor	Sambar deer	69	0.32	6
			Rucervus eldii/ Rucervus schomburgki	Eld's deer/ Schomburgk's deer	950	4.46	33

			Rucervus eldii	Eld's deer	5	0.02	3
			Axis porcinus/ Muntiacus muntjak	Hog deer/ Barking deer	143	0.67	9
			Muntiacus muntjak	Barking deer	1	0.005	1
	Perissodactyla	Rhinocerotidae		Rhino	8	0.04	1
	Proboscidea	Elephantidae	*Elephas maximus*	Asian elephant	1	0.005	1
Mammalia (small)				Small mammal	107	0.5	9
	Lagomorpha	Leporidae	*Lepus* sp(p).	Hare	1	0.005	1
	Rodentia	Rhizomyinae (Subfamily)		Bamboo rat	1	0.005	1
		Muridae		Mouse and rat	255	1.2	26
			Bandicota sp(p).	Bandicoot rat	17	0.08	4
			Bandicota indica	Greater bandicoot rat	2	0.01	2
			Bandicota savilei	Savile's bandicoot rat	3	0.01	1
			Berylmys sp(p).	White toothed rat	1	0.005	1
			Niviventer sp(p).	White bellied rat	5	0.02	2
			Rattus sp(p).	True rat	2	0.01	2
			Mus sp(p).	Mouse	2	0.01	1
Actinopterygii (ray-finned fish)	Cypriniformes	Cyprinidae		Carp/ minnow	30	0.14	17
			Hampala sp(p).	Jungle perch	4	0.02	1
	Osteoglossiformes	Notopteridae	*Notopterus notopterus*	Bronze featherback	23	0.11	4
	Siluriformes	Siluridae		Catfish	50	0.23	8
			Wallago sp(p).	Wallago catfish	29	0.14	3

		Ompok bimaculatus	Butter catfish	351	1.65	34
	Pangasiidae		Shark catfish	2	0.01	1
	Bagridae		Naked catfish	914	4.29	79
		Hemibagrus sp(p).	Yellow catfish	236	1.11	23
		Mystus sp(p).	Tengra catfish	54	0.25	3
	Clariidae	*Clarias* sp(p).	Walking catfish	2623	12.32	89
		Clarias macrocephalus	Broadhead catfish	2	0.01	2
Synbranchiformes	Synbranchidae	*Monopterus albus*	Asian swamp eel	865	4.06	84
Perciformes	Channidae	*Channa* sp(p.)	Snakehead fish	19	0.09	4
		Channa lucius	Forest snakehead	41	0.19	5
		Channa striata	Snakehead murrel	4696	22.06	218
		Channa micropeltes	Giant snakehead	12	0.06	2
	Nandidae	*Pristolepis fasciata*	Malayan leaf fish	19	0.09	8
	Anabantidae	*Anabas testudineus*	Climbing perch	2584	12.14	190
	Osphronemidae		Gourami	10	0.05	4

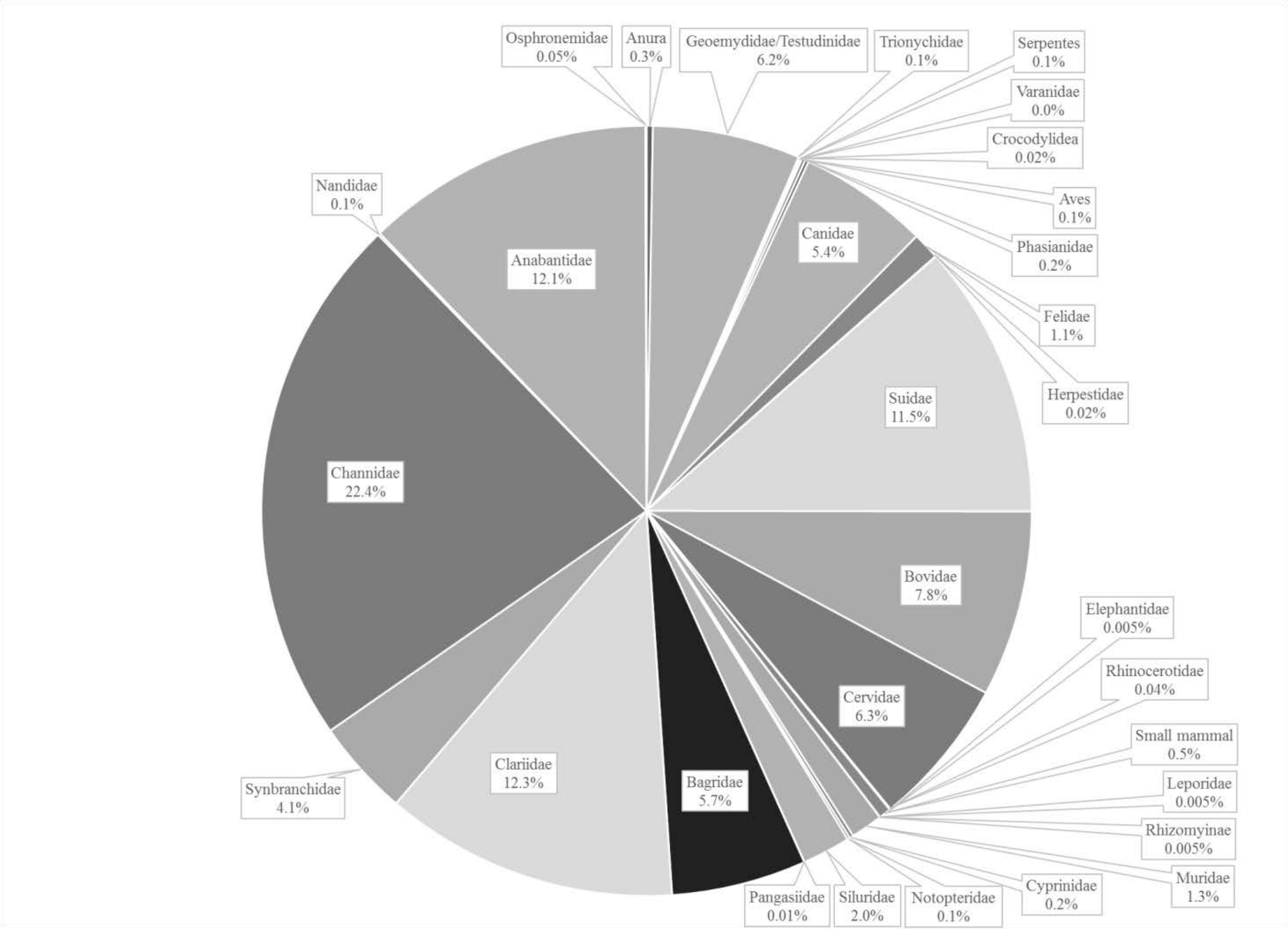


Figure 39: The relative frequency of NISP by family, order, or class level at BNW

5.2.3 Identifying Members of the Bovidae Family

Two hundred and seventy-five bone elements from the excavation of BNW were used to identify genera of *Bos* and *Bubalus*. Nineteen metacarpals were identified as *Bubalus* from visual inspection and from measurements of the proximal and distal ends (Appendix D, Figure 40). Eighteen metacarpals were identified as belonging to *Bos*. Fifteen metatarsal were identified as *Bubalus* and 15 as *Bos* (Appendix E). Two proximal metatarsals fragment from S400 (2:11) Feature 8 and U200 (7:3) Feature 30 were substantially larger than the mean value of *Bos taurus* metatarsal measurements. These two proximal metatarsal fragments are, therefore, most likely from *Bos gaurus* or *Bos javanicus*.

Figure 40: Cranial view of the metacarpals of *Bubalus* and *Bos*. From the top; left metacarpal of *Bubalus* sp. from BNW, right metacarpal of *Bubalus bubalis* from the comparative collection, right metacarpal of *Bos* sp. from BNW, right metacarpal of *Bos taurus* from the comparative collection.

Thirteen magnums were identified as belonging to the *Bos* and *Bubalus* genera from visual inspection and measurements. Five right and four left magnums were identified as *Bubalus,* and one right and three left magnums as *Bos* (Appendix

F). Two left magnums from K500 (3:5) feature were above the mean of female *Bubalus bubalis* magnum measurements. It is possible that these magnums were from wild water buffalo, *Bubalus arnee*. However, they could also be from a larger male *Bubalus bubalis*.

Ninety-six first phalanges from BNW could be identified as either *Bos* or *Bubalus* (Appendix G). Forty-five of the first phalanges were identified as *Bubalus* phalanges. The measurement values of the six *Bubalus* phalanges from N100 (8:5 and 8:6) general spit, I500 (2:10) general spit, JI500 (3:12) general spit, TU199-200 (3:1) feature 5, and Z201 (4:2) general spit were substantially above the mean for *Bubalus bubalis* female measurements. It is possible that the phalanges were from wild water buffalo, *Bubalus arnee*. Fifty-one of the 96 first phalanges from BNW were identified as *Bos*. Two first phalanges from P300 (3:5) Feature 1 and N96 (3:3) general spit were closer in size to wild cattle species *Bos gaurus* and *Bos javanicus*. In addition to the phalanges identified by measurements, 58 third phalanges were visually identified as *Bos* and *Bubalus*, with the aid of the comparative collection. Forty-one of the 58 third phalanges were identified as *Bubalus* and 17 were *Bos*.

5.2.4 Identifying Members of the Cervidae Family

Six antlers were identified from BNW. Five fragments were identified as Eld's deer, one with the pedicle and burr present, three with just the burr, and one fragment (Figure 41). The third antler identified was a complete barking deer antler (Figure 42). No antler was definitively identified as Schomburgk's deer or sambar deer, although there were fragments of antler that had a large diameter and were most likely from these larger species.

Figure 41: *Rucervus eldii* antler fragments from BNW

Figure 42: *Muntiacus muntjak* antler from BNW

5.2.5 Identifying Members of the Muridae Family

From the measurements of mice and rat teeth, and the comparison with modern samples, five genera of rats and mice were identified at BNW (Appendix H). The *Bandicota* genus was the most commonly identified, with 22 specimens. Five of the 22 were identified to species level. Three were identified as savile's bandicoot rat (*Bandicota savilei*) and two as the greater bandicoot rat (*Bandicota indica*) (Figure 43). The second most commonly identified was the *Niviventer* genus. Based on the modern distribution of the *Niviventer*, the identified specimens are more likely to be the species *Niviventer fulvescens*, the Chestnut White-bellied Rat. However, these specimens could also be Limestone Rat, *Niviventer hinpoon*. Members from the *Mus*, *Rattus*, and *Berylmys* genera were also identified in low numbers. As well as the five genera of rats and mice identified at BNW, a maxilla was identified from the subfamily Rhizomyinae in the Family Spalacidae (Figure 44)

Figure 43: The mandibles from *Bandicota indica* (top row) and *Bandicota savilei* (bottom row)

Figure 44: A maxilla from the subfamily Rhizomyinae

5.2.6 The Frequency of Skeletal Elements from Bovidae, *Sus,* and Cervidae

The skeletal elements were grouped by time period at BNW. The identified Bovidae elements from the Iron Age at BNW show a higher relative frequency of phalanx and sesamoid elements in all time periods (Figure 45). The upper forelimb elements were identified in relatively similar amounts throughout all time periods. The upper hindlimb elements were identified in higher amounts in the Neolithic than the Iron and Bronze Age at BNW. The carpal and metacarpal elements were identified in lower amounts in the Neolithic, however the tarsal and metatarsal elements were similar throughout all time periods. The cranial elements were the same percentage in the Bronze Age and Neolithic periods, and were lower in the Iron Age.

Sus scrofa grouped skeletal elements at BNW displayed a high percentage of meat-bearing bones in all time periods represented by upper forelimb, cranial elements, and upper hindlimb elements (Figure 46). The lower forelimb and hindlimb elements, including the carpal, metacarpal, tarsal, metatarsal, and phalanx elements, were lower in number in all time periods in comparison to the other *Sus scrofa* elements identified (Figure 46).

All grouped skeletal elements identified as Cervidae at BNW showed relatively similar frequencies throughout all time periods, except for the carpal and metacarpal elements which were lower in the Iron Age and Bronze Age periods (Figure 47). Additionally the phalanx and sesamoid elements were lower in the Iron Age period (Figure 47).

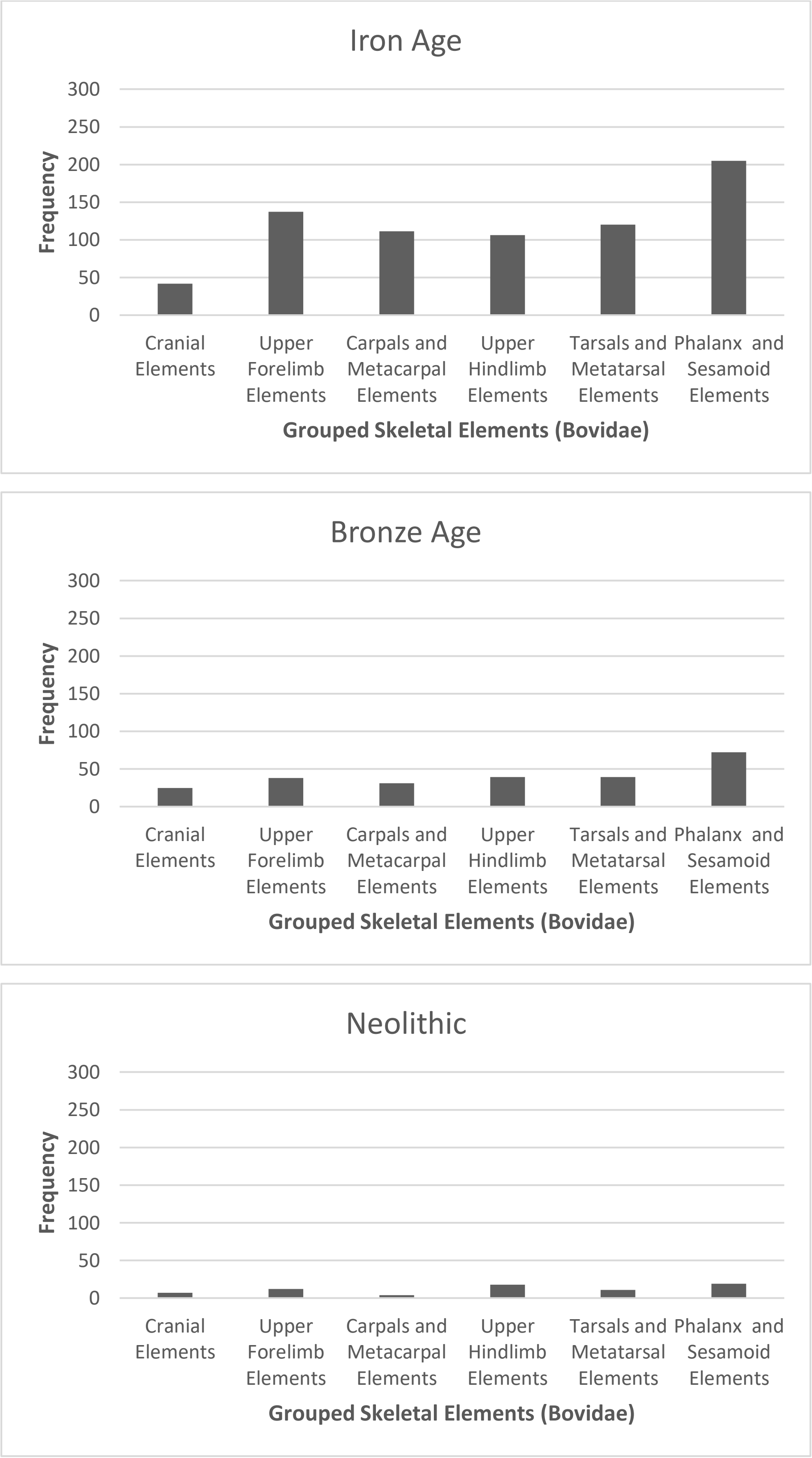


Figure 45: The frequency of Bovidae elements from the cranial, upper forelimb, carpal and metacarpal, upper hindlimb, tarsal and metatarsal, and the phalanx and sesamoid, from the Iron Age, Bronze Age, and Neolithic at BNW

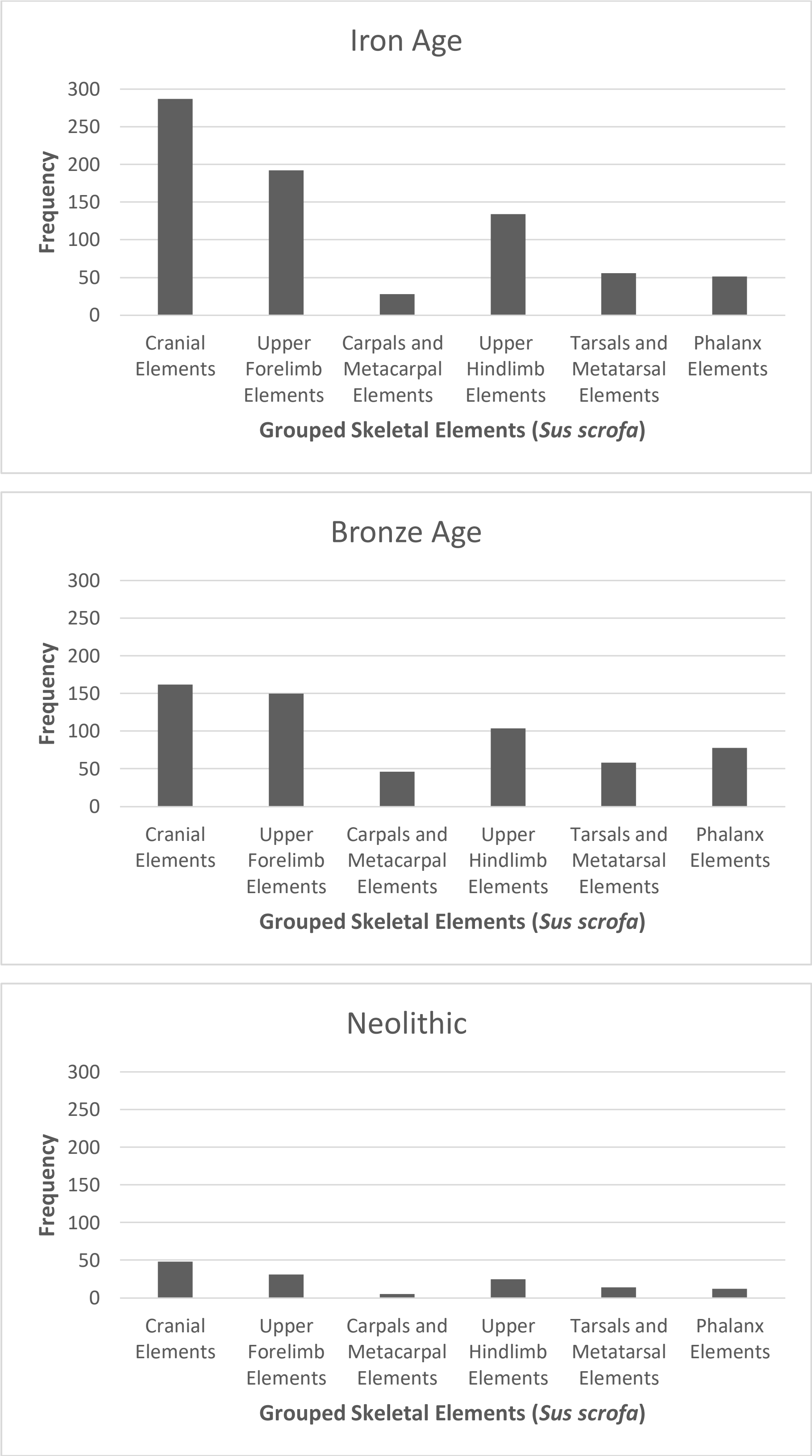


Figure 46: The frequency of *Sus scrofa* elements from the cranial, upper forelimb, carpal and metacarpal, upper hindlimb, tarsal and metatarsal, and phalanx, from the Iron Age, Bronze Age, and Neolithic at BNW

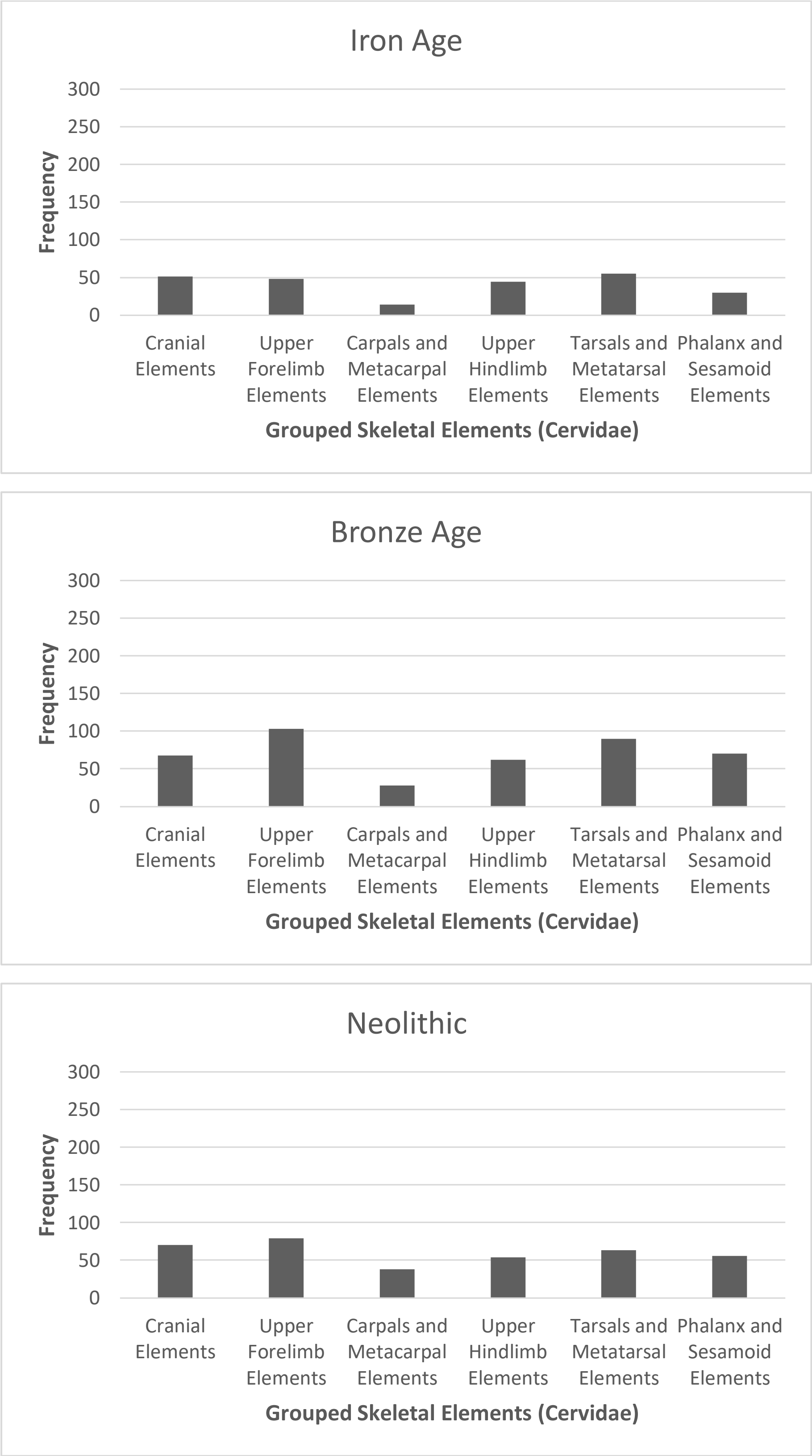


Figure 47: The frequency of Cervidae elements from the cranial, forelimb, carpal and metacarpal, hindlimb, tarsal and metatarsal, and phalanx, from the Iron Age, Bronze Age, and Neolithic at BNW

5.2.7 NISP by Context

NISP values for the more commonly identified mammals found in general spit, feature, and burial contexts at BNW are presented in Figure 48. The pig remains were found equally in general spit and feature contexts. Pig remains came from a range of features including post holes, pits, middens, hard floors, pottery concentrations, and channels. Bovid remains were found in features more often than in the general spit contexts. The majority of bovid remains came from bone midden features. Bone midden features are further analysed at BNW in: *5.2.9 The Iron Age bone midden features*. Both the Eld's or Schomburgk's deer and hog or barking deer were frequently found in general spit contexts. A large number of deer remains came from bone midden features. The most commonly identified fish remains came from general spit, feature, and grave fill in relatively equal amounts (Figure 49). The climbing perch was found more often in feature and grave fill contexts than general spits. All fish remains came from a range of features, including post holes, pits, middens, hard floors, pottery concentrations, and channels. The low NISP values in burial contexts is mostly due to a larger volume of sediment being removed from the general spit and feature contexts in comparison to burial contexts. Likewise, the high NISP values in fish taxa in the grave fill is due to wet sieve sampling of these contexts.

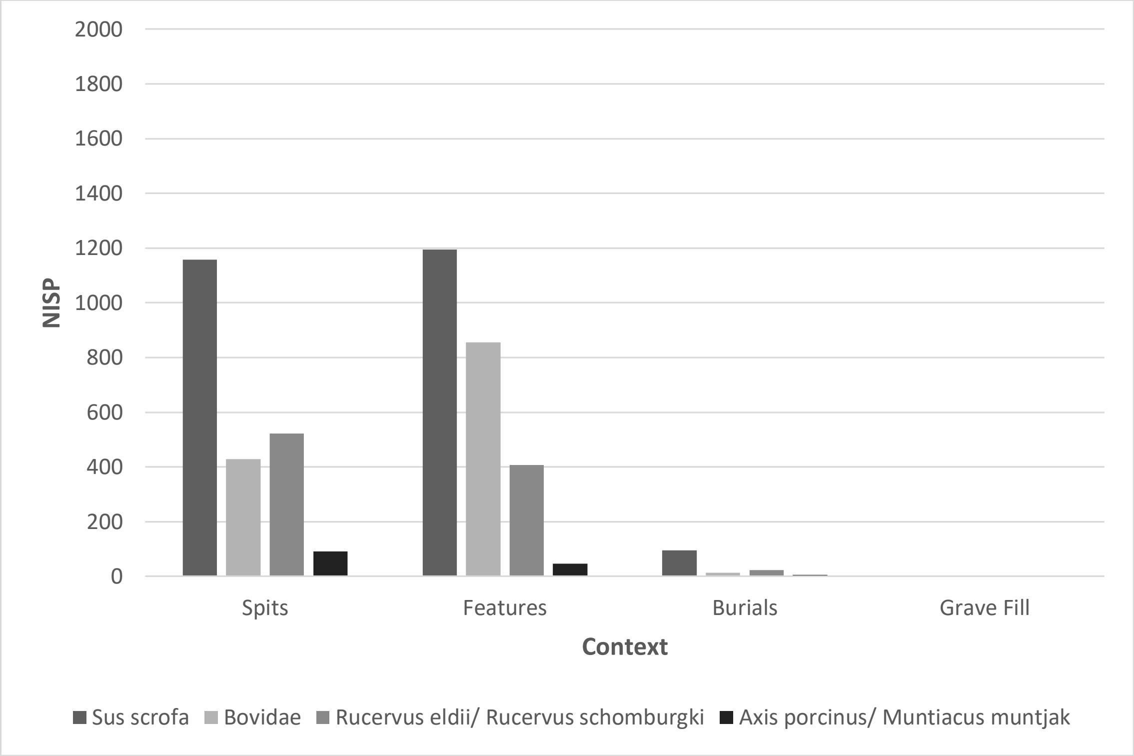


Figure 48: The NISP value for the more frequently identified mammal taxa by context type from all periods at BNW

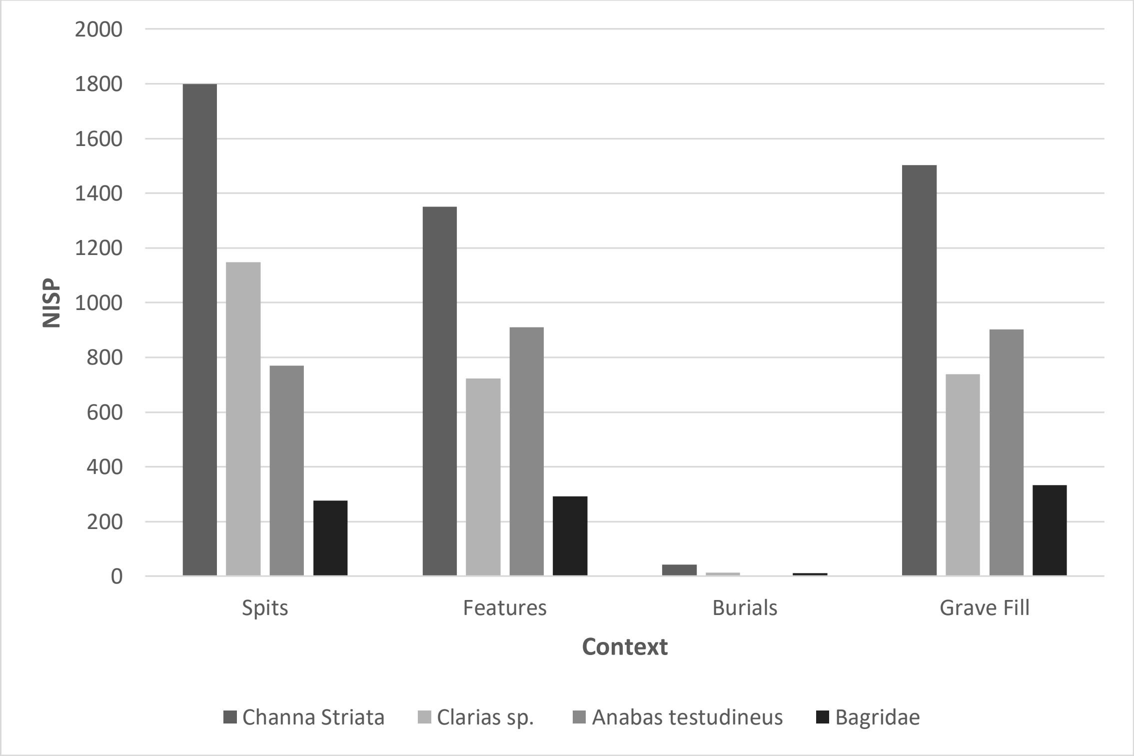


Figure 49: The NISP value for the more frequently identified fish taxa by context type from all periods at BNW

5.2.8 Frequency of NISP by Volume (m^3) Over Time

The frequency of NISP by volume (m^3) through time from the hand collected and dry sieved data at BNW are presented in Figure 50, Figure 52, Figure 54, Figure 56, and Figure 58. The BNW Iron Age hand collected and dry sieved data shows pig was the highest represented taxon by volume, followed by bovid (Figure 54). Domestic dog remains were also found in high numbers. Although, this number was inflated by the dog burial found in the Iron Age contexts at BNW. In the Bronze Age the four highest represented taxa were pig, turtle and tortoise, Eld's and Schomburgk's deer, and bovid (Figure 56). The four highest represented taxa in the Neolithic were turtle and tortoise, dog, Eld's and Schomburgk's deer, and pig (Figure 58). Turtle and tortoise remains were found in large amounts in the Neolithic shell midden feature at BNW. Dogs were the highest mammal taxon by volume found in Neolithic contexts at BNW. However, this number was enlarged by the dog burial in excavation unit G104. The Eld's and Schomburgk's deer were found in greater amounts than that of pig or bovid, in Neolithic contexts. NISP by volume of the hand collected and dry sieved data from Historic and Modern periods at BNW were noticeably lower. Bovid and pig was the highest taxa by volume found in Historic and Modern contexts (Figure 50, Figure 52). A comparison of the NISP by volume (m^3) of the most repeated taxa (order and family) from hand collected and dry sieved data through time at BNW is presented in Figure 60. This excludes the NISP from burials of whole animals, as these would inflate the numbers of NISP in the taxa.

The frequency of NISP by volume (m^3) through time from the wet sieve sample at BNW are presented in Figure 51, Figure 53, Figure 55, Figure 57, and Figure 59. The four highest represented taxa in the Iron Age, Bronze Age, and Neolithic were the snakehead murrel, walking catfish, climbing perch, and Asian swamp eel. The snakehead murrel was the most frequent in all time periods, except for the Historic period where the walking catfish was the highest taxa represented (Figure 53). The walking catfish is the second most numerous NISP by volume in the Iron Age, equal with climbing perch in the Bronze Age, and third most frequent after the climbing perch in the Neolithic contexts. This is reflected in the comparison of the NISP by volume (m^3) of the most repeated taxa (genus) from the wet sieve sample through time at BNW presented in Figure 61.

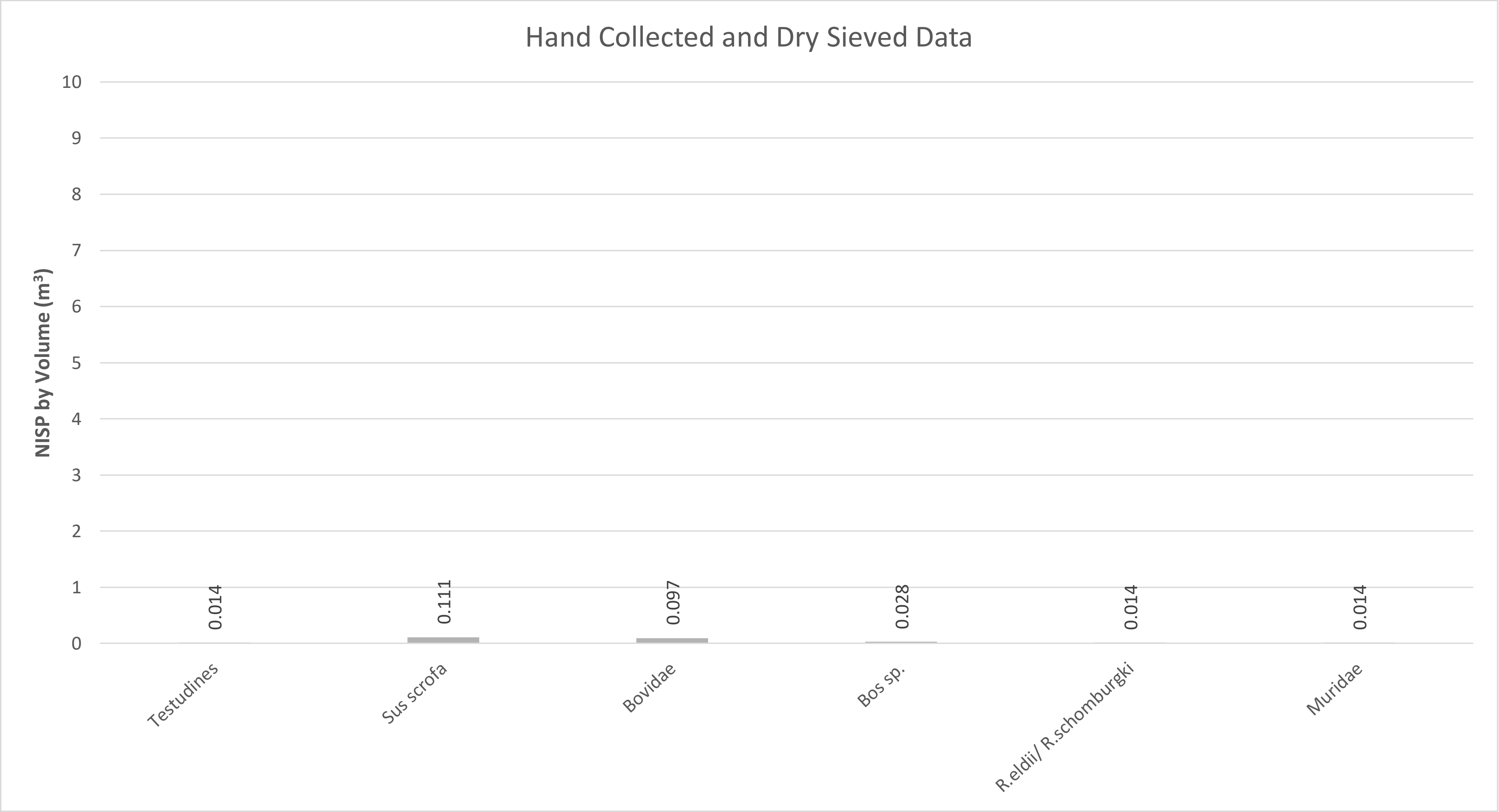


Figure 50: The frequency of NISP by volume (m^3) from hand collected and dry sieved data in the Modern period at BNW

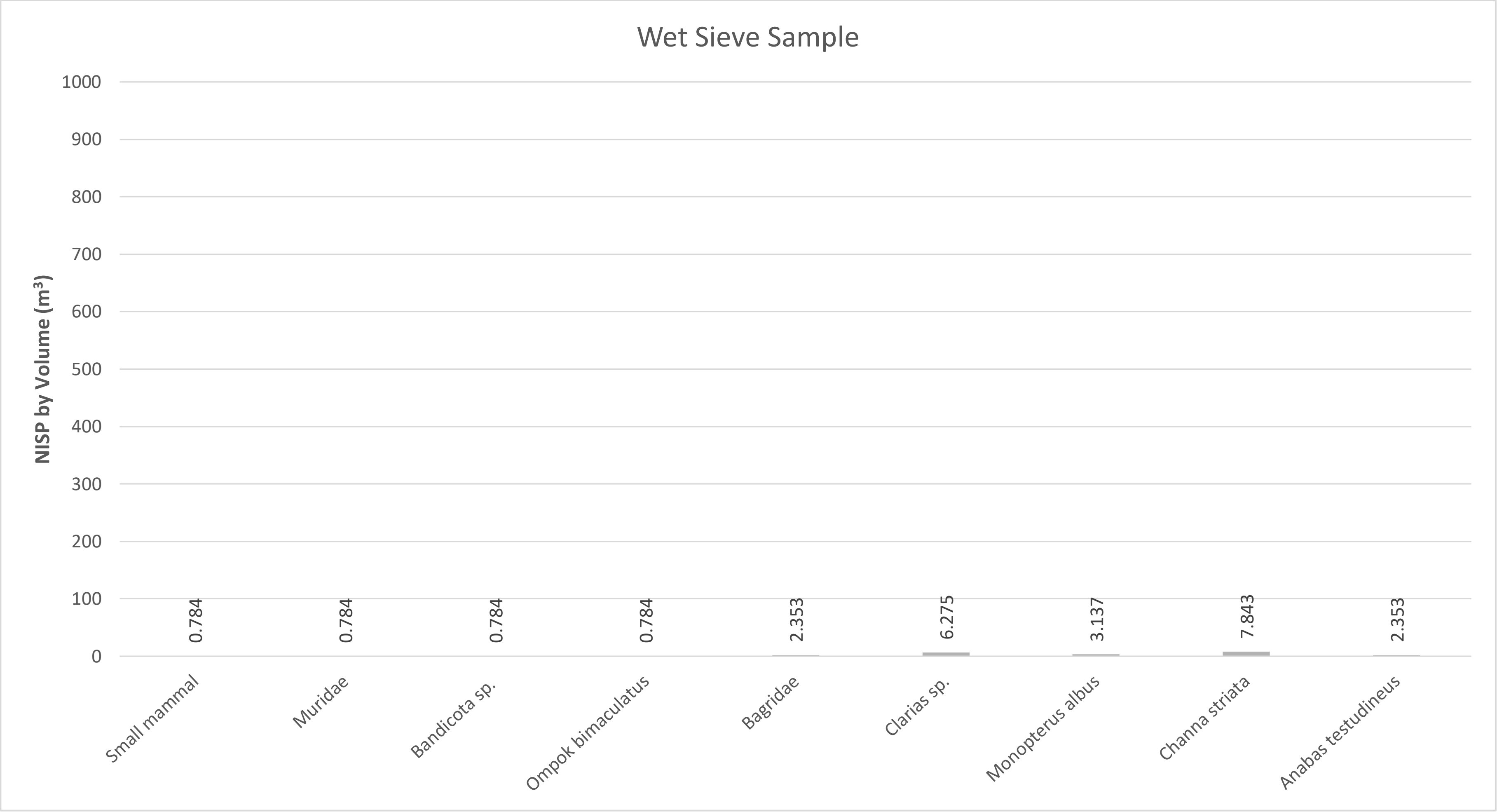


Figure 51: The frequency of NISP by volume (m^3) from the wet sieve sample in the Modern period at BNW

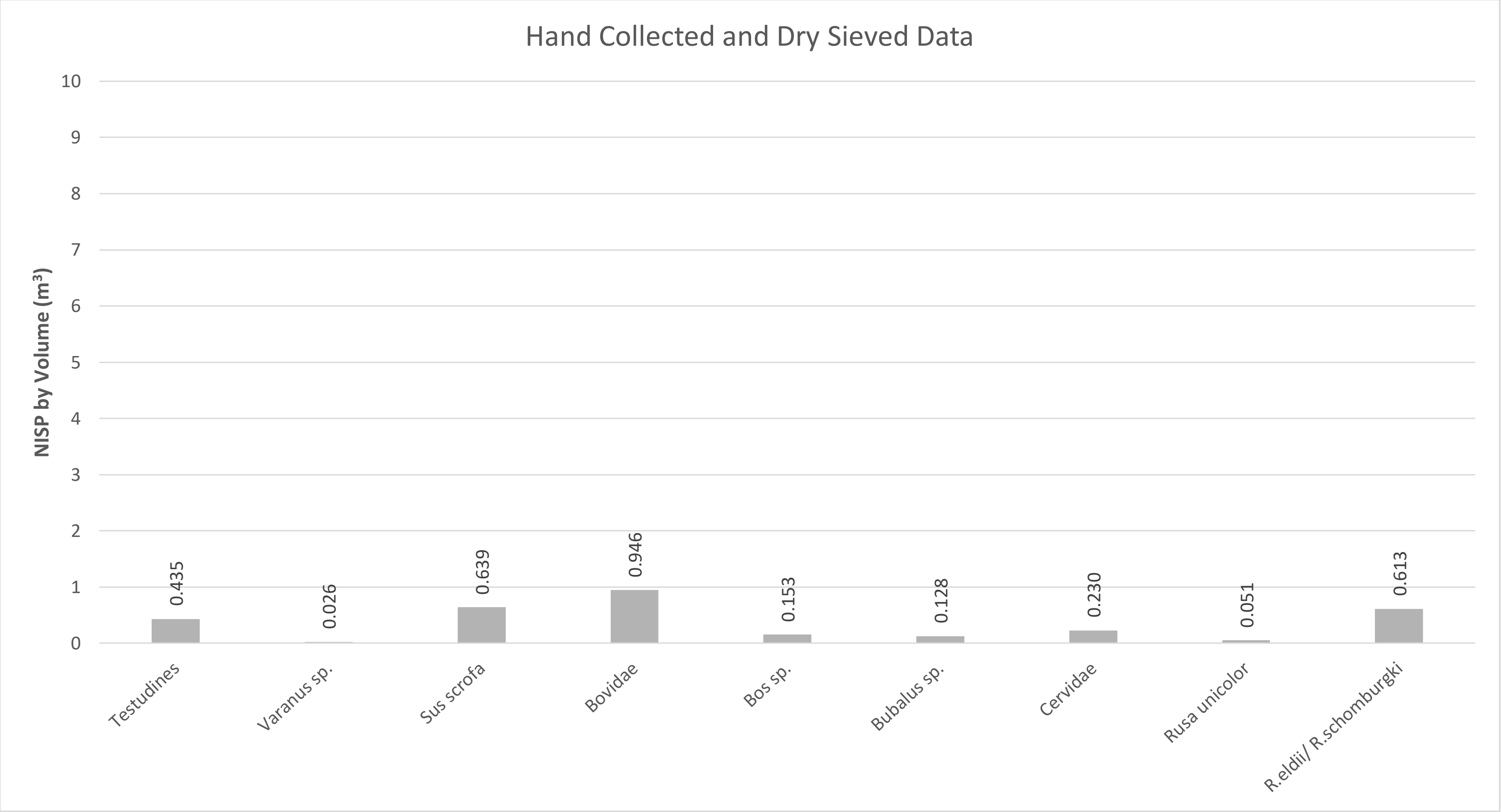


Figure 52: The frequency of NISP by volume (m^3) from hand collected and dry sieved data in the Historic period at BNW

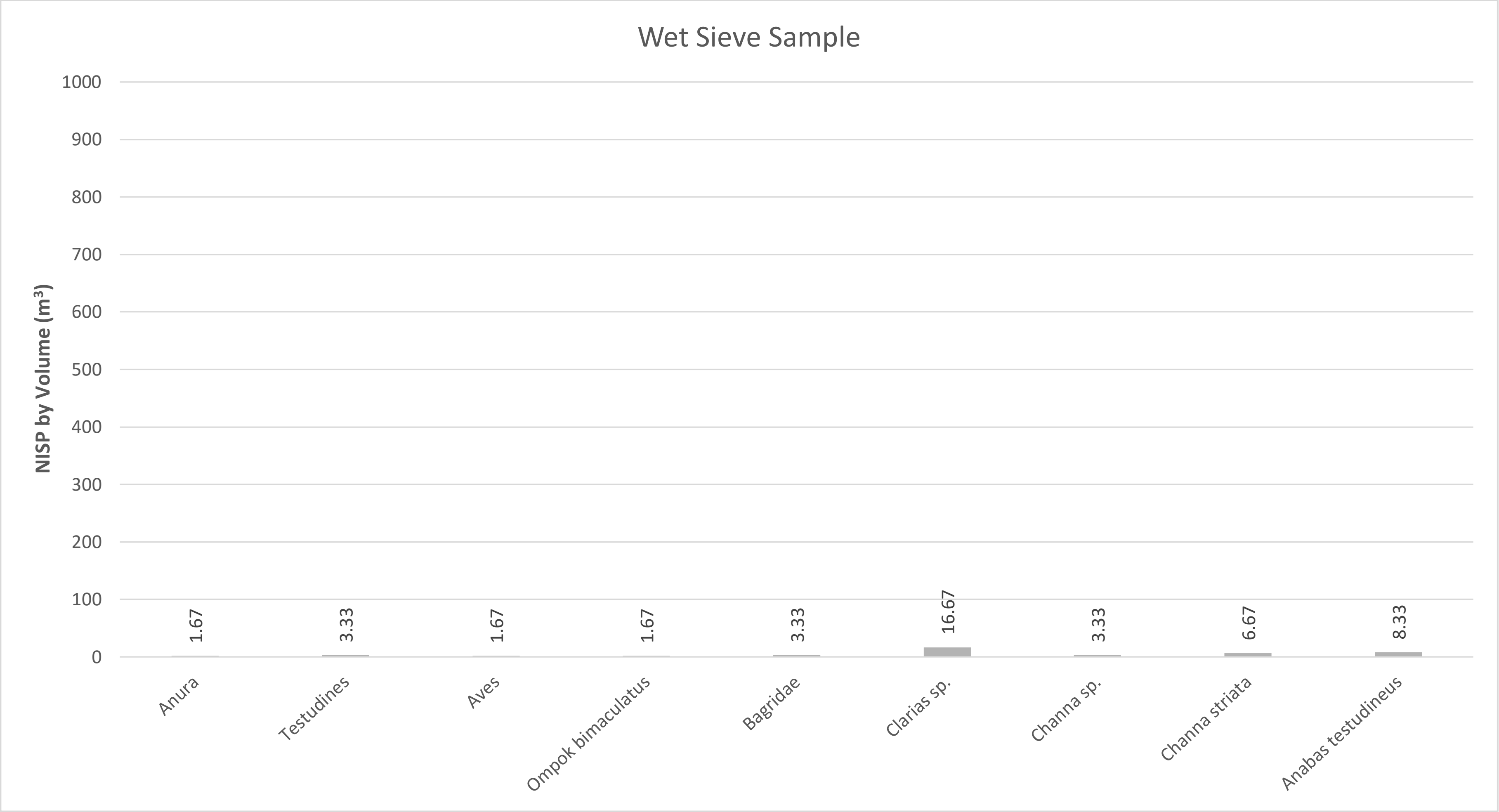


Figure 53: The frequency of NISP by volume (m^3) from the wet sieve sample in the Historic period at BNW

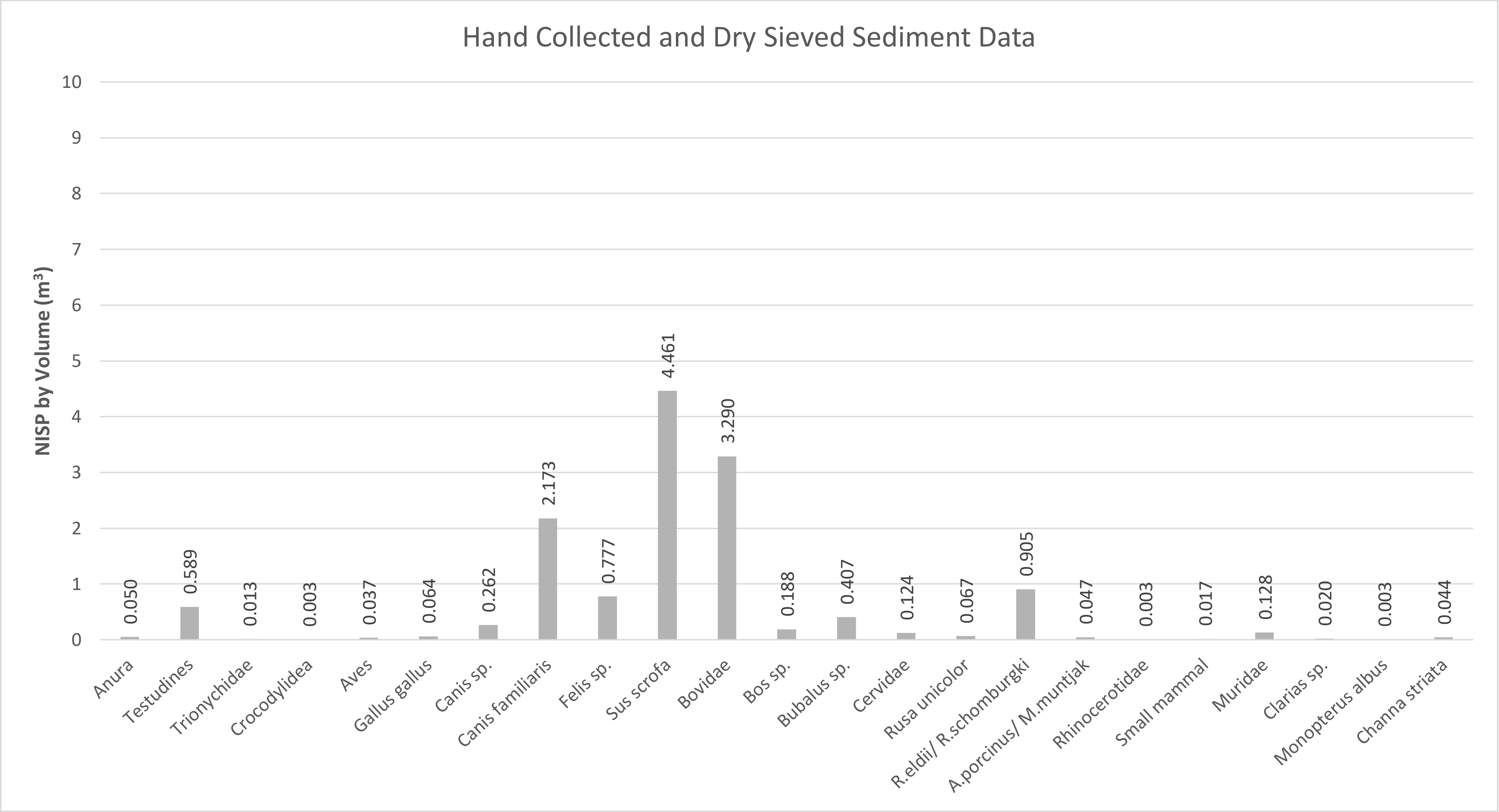


Figure 54: The frequency of NISP by volume (m^3) from hand collected and dry sieved data in the Iron Age at BNW

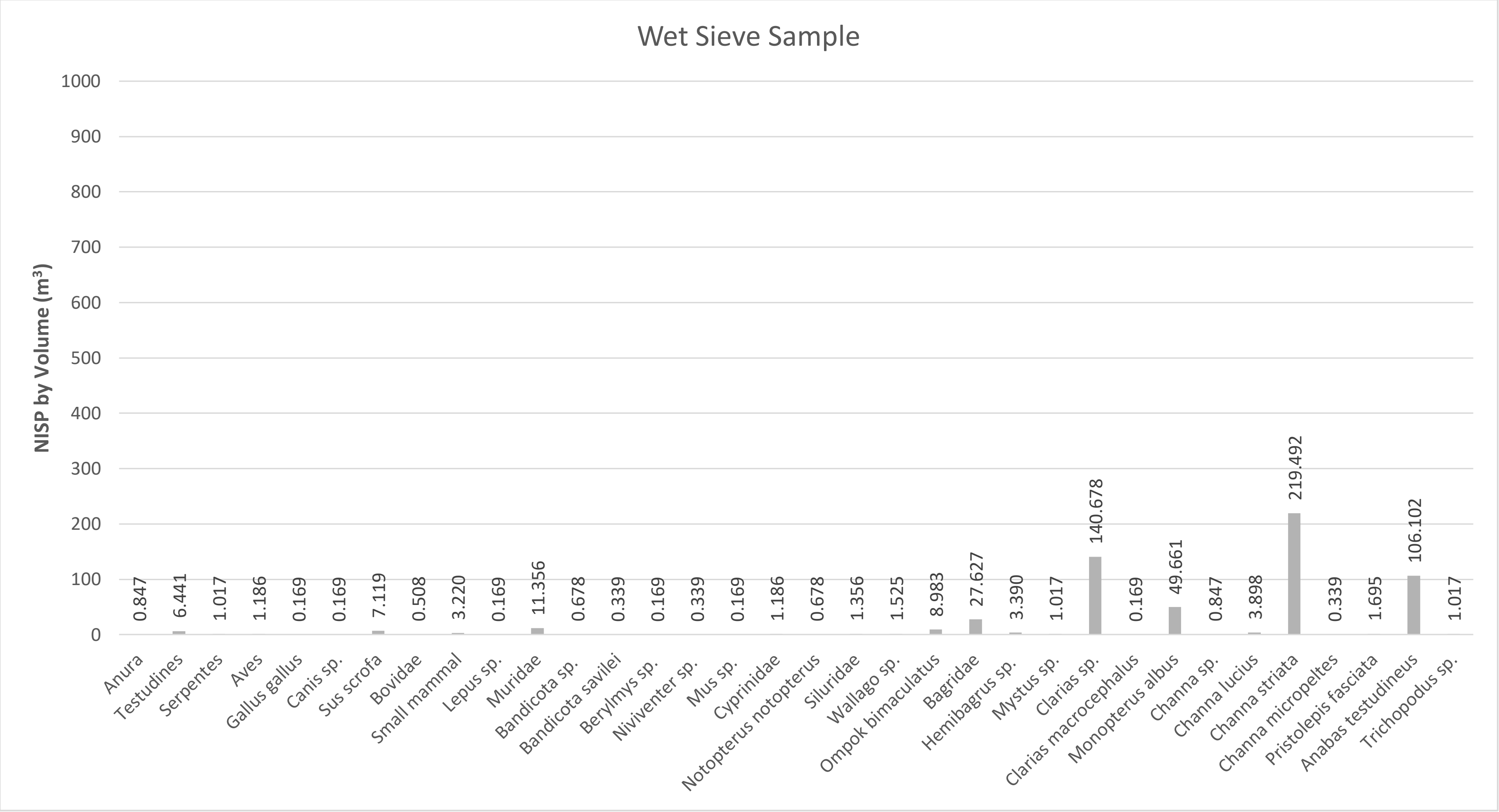


Figure 55: The frequency of NISP by volume (m^3) from the wet sieve sample in the Iron Age at BNW

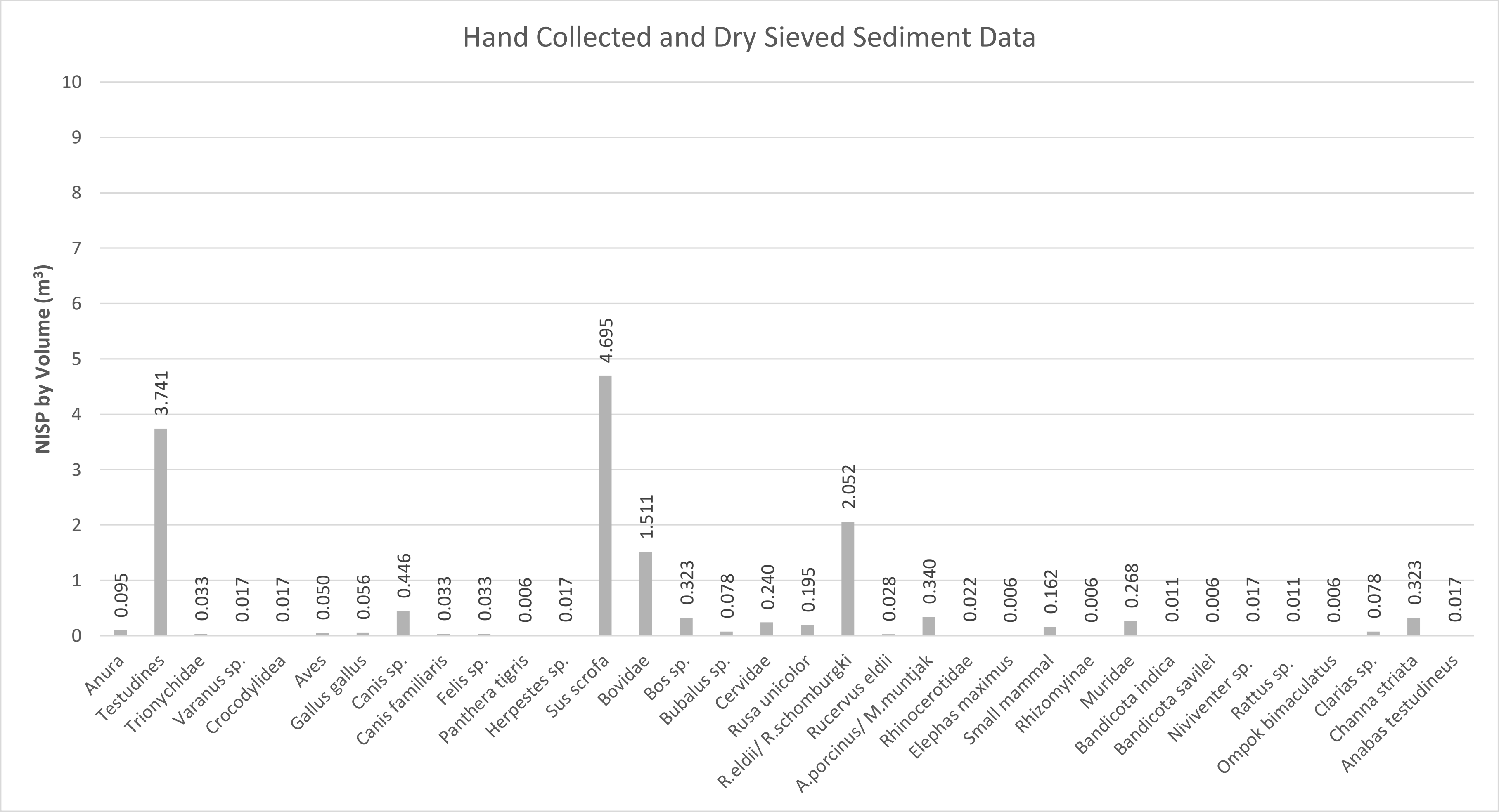


Figure 56: The frequency of NISP by volume (m^3) from hand collected and dry sieved data in the Bronze Age at BNW

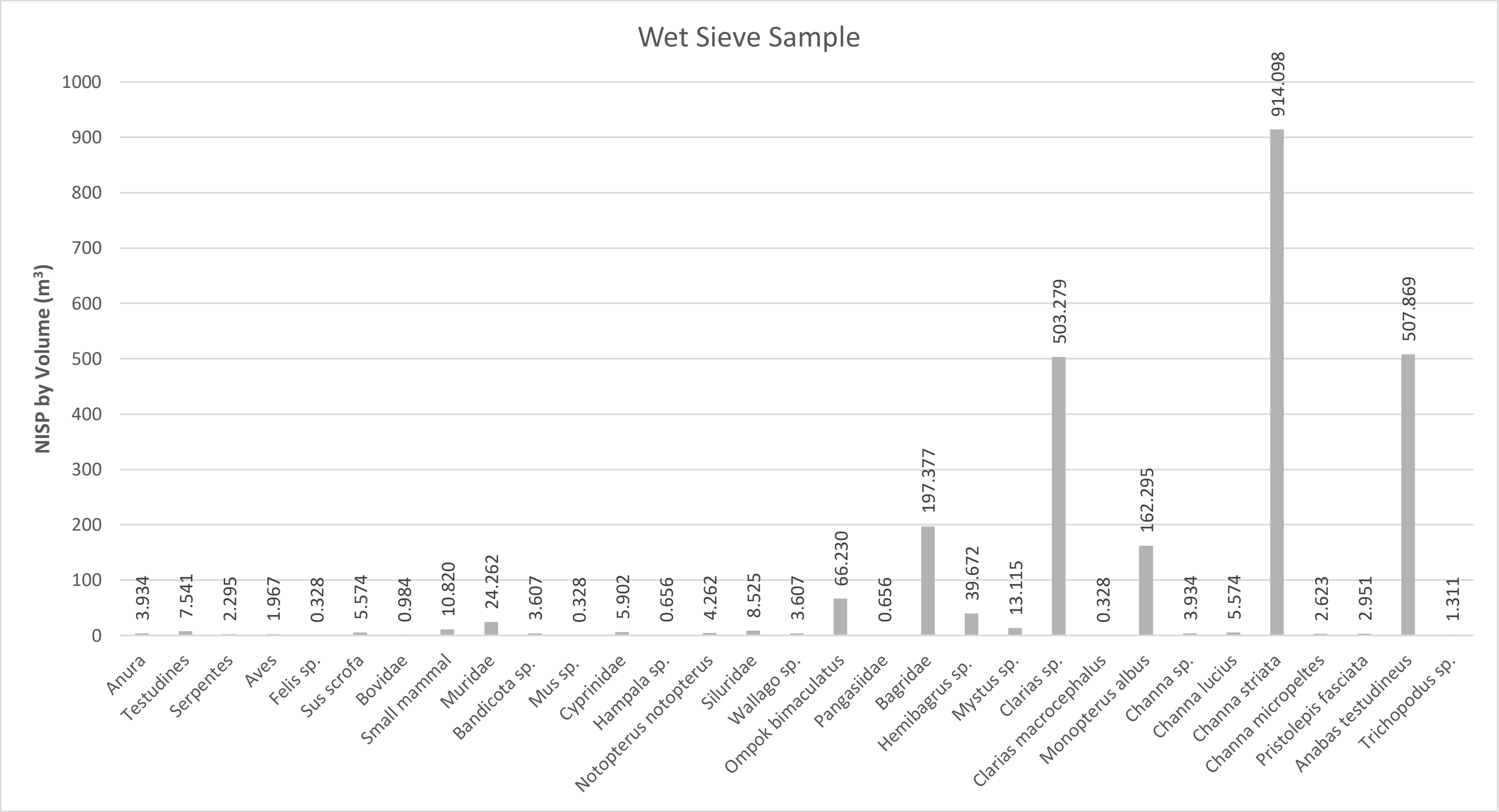


Figure 57: The frequency of NISP by volume (m^3) from the wet sieve sample in the Bronze Age at BNW

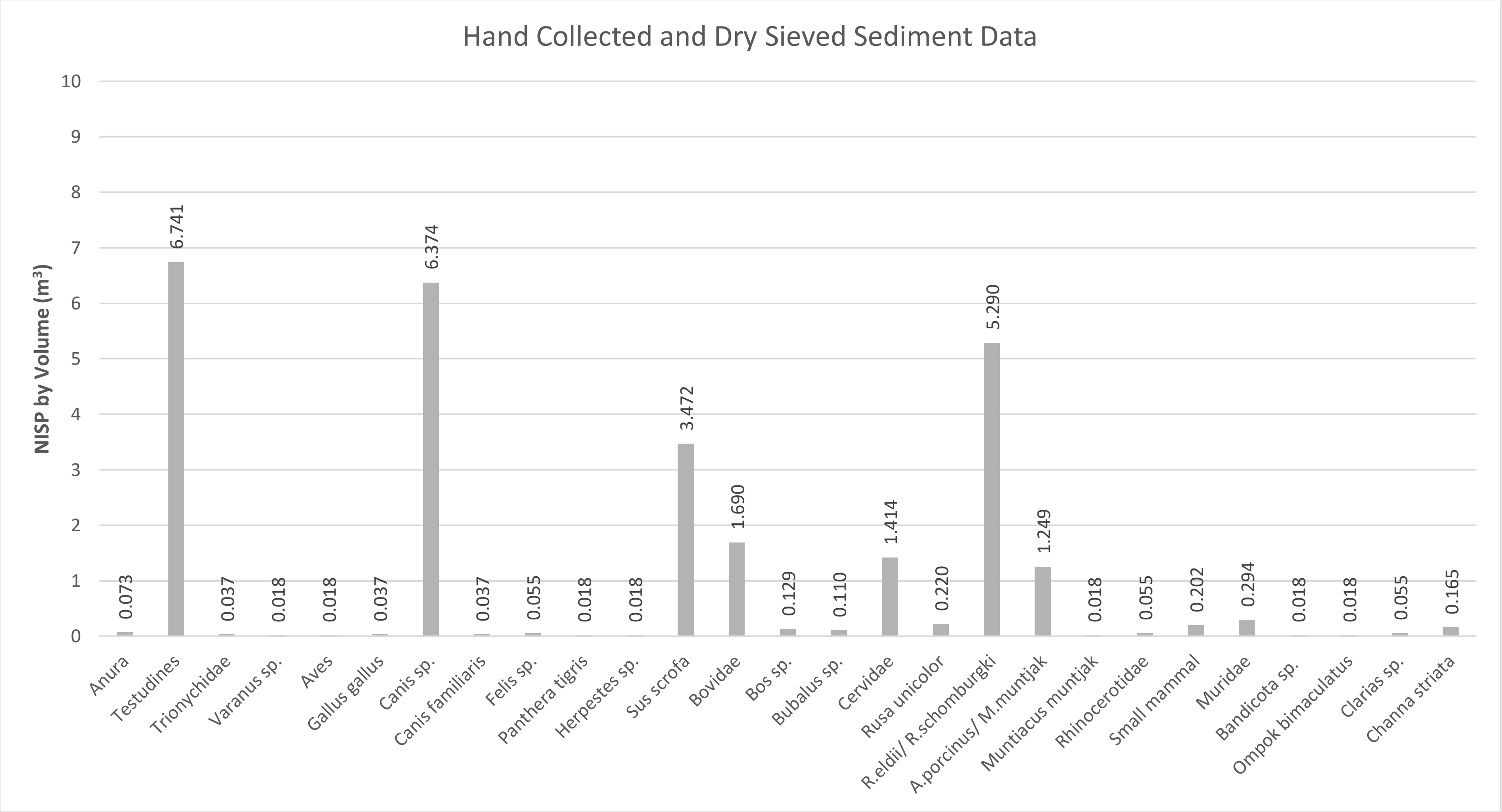


Figure 58: The frequency of NISP by volume (m^3) from hand collected and dry sieved data in the Neolithic at BNW

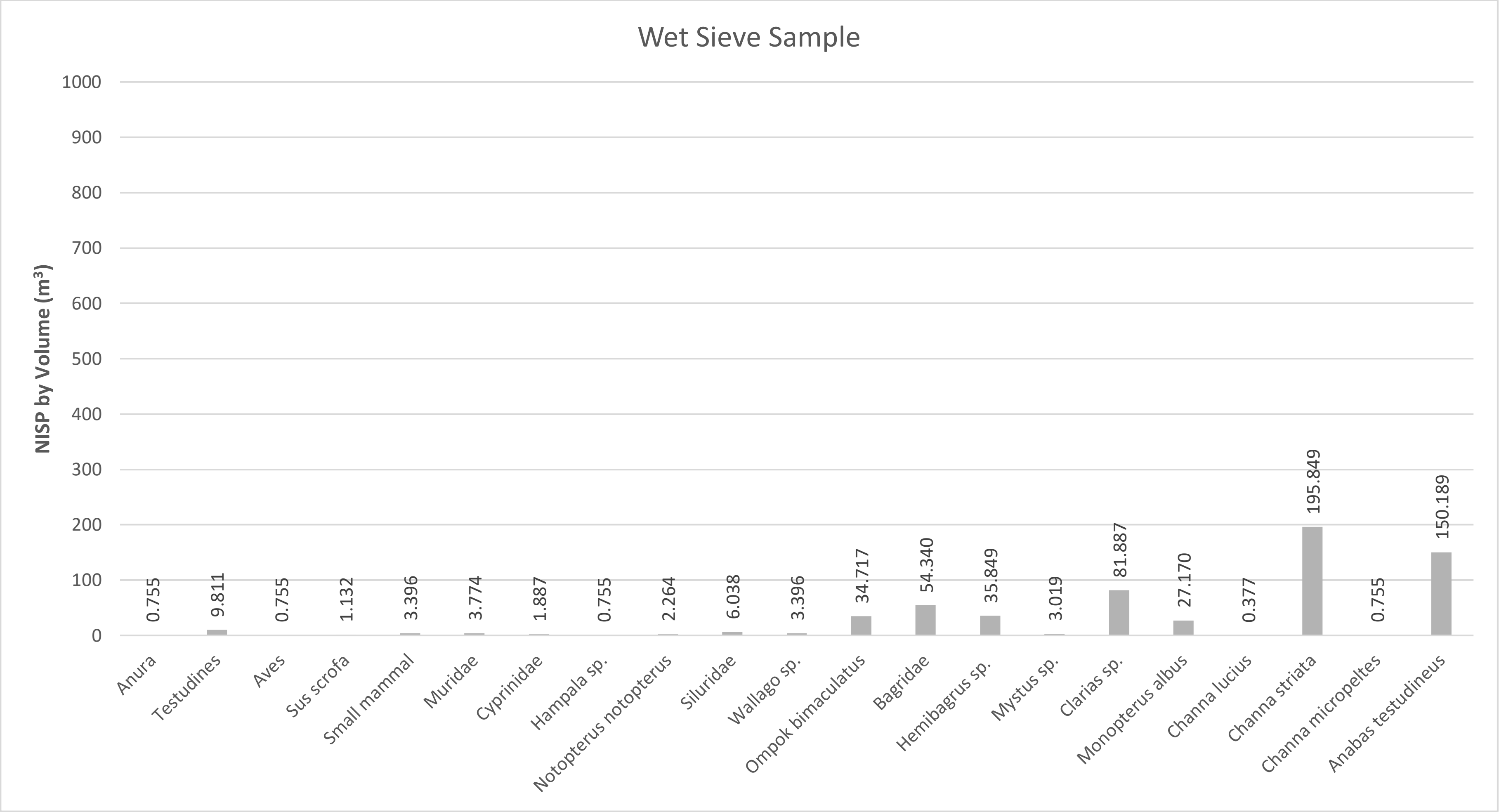


Figure 59: The frequency of NISP by volume (m^3) from the wet sieve sample in the Neolithic at BNW

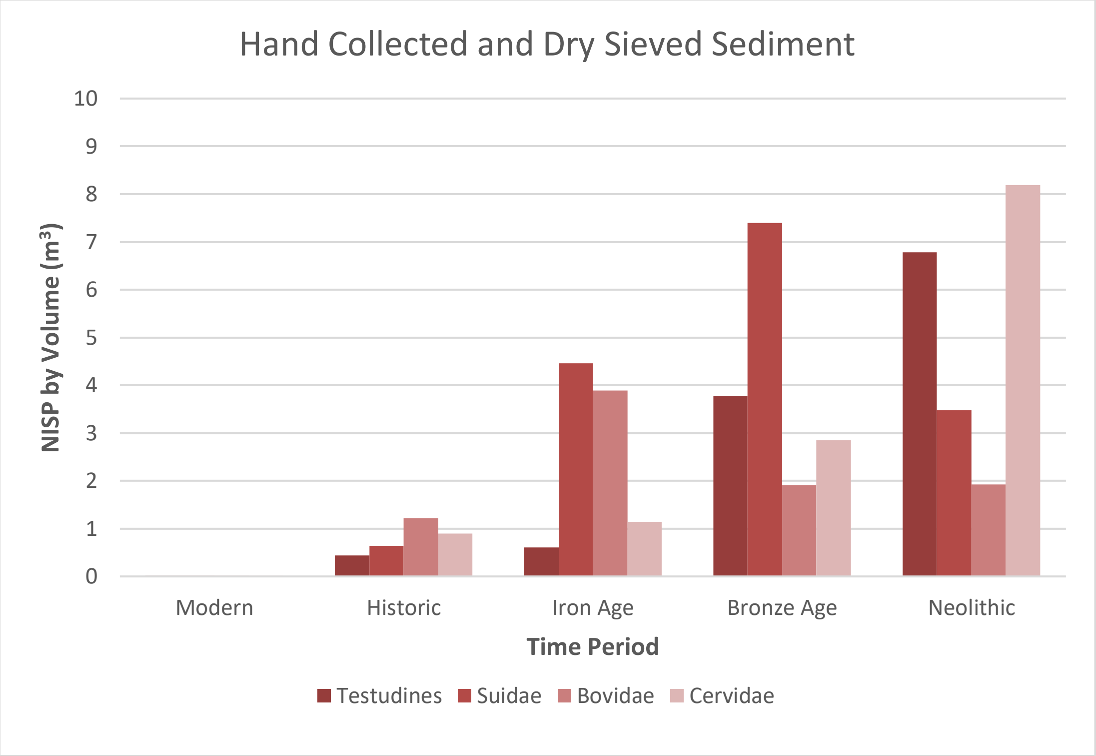


Figure 60: The frequency of NISP by volume (m^3) over time of the most repeated taxa (order and family) from hand collected and dry sieved data at BNW

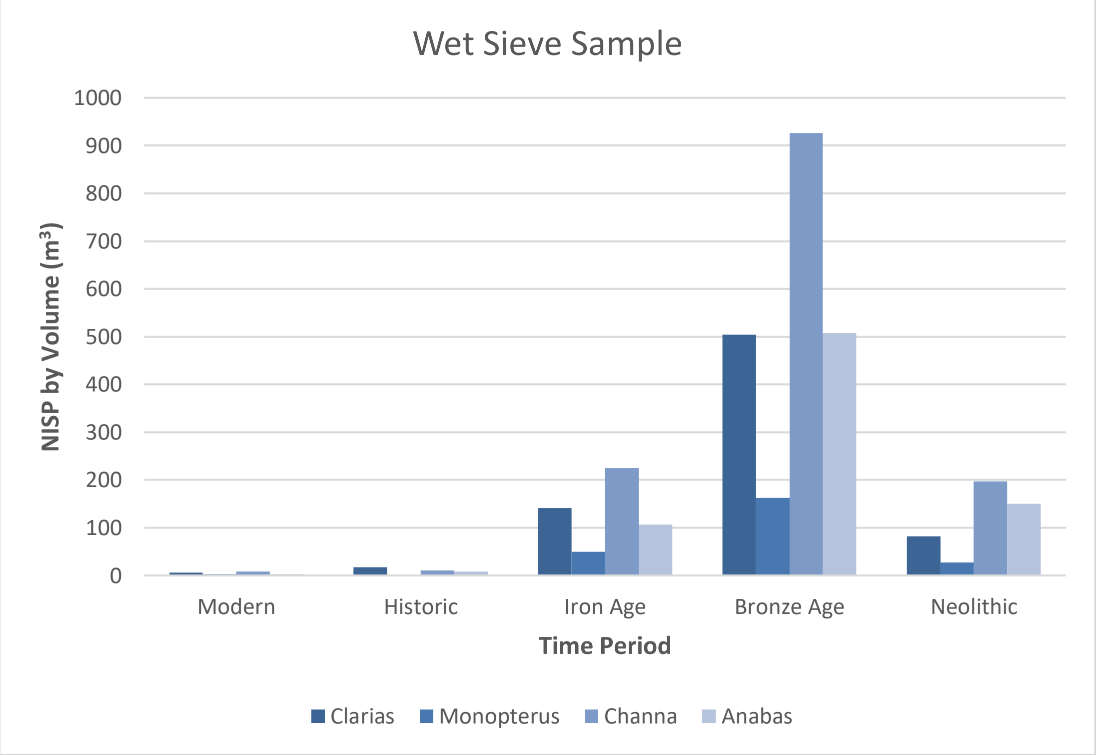


Figure 61: The frequency of NISP by volume (m^3) over time of the most repeated taxa (genus) from the wet sieve sample at BNW

5.2.9 The Iron Age Bone Midden Features

Two Iron Age bone midden features were uncovered during the excavation of BNW. One was located to the north of the centre of the mound in excavation unit N96 (Figure 62), the other to the northeast of the centre in excavation unit K500 (Figure 64). The two bone midden features at BNW contained a high amount of bovid bones (Figure 63 and Figure 65): 45 per cent in unit N96 and 65 per cent in unit K500. The ratio of identifiable elements of water buffalo to cattle was 20:1, whilst the ratio of identifiable elements of water buffalo to cattle in unit K500 was 1.2:1. It was also noted that most of the cattle bones from the bone midden feature in unit K500 were large in size and were most likely from a wild cattle.

Figure 62: The Iron Age bone midden feature in N96, layer three at BNW, facing west (image by Chang, 2009)

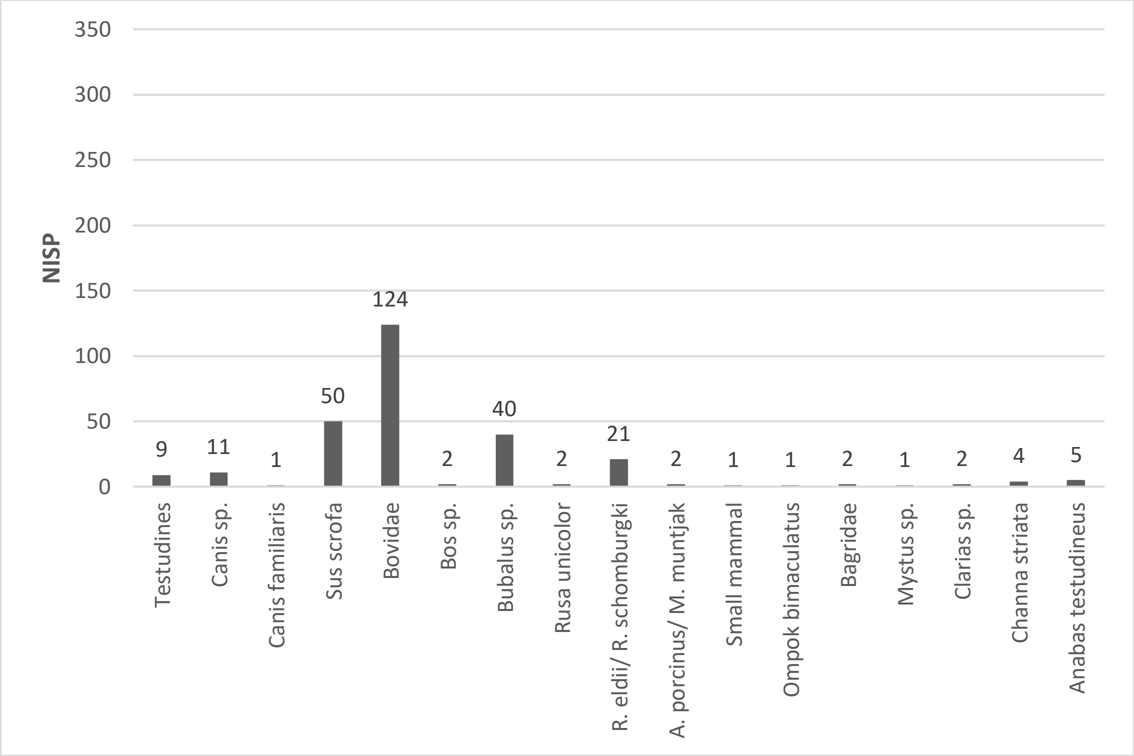


Figure 63: The frequency of NISP in the bone midden feature 1 layer 3 spit 3, N96 at BNW

Figure 64: The Iron Age bone midden feature in K500, layer three at BNW, facing south (image by Chang, 2010)

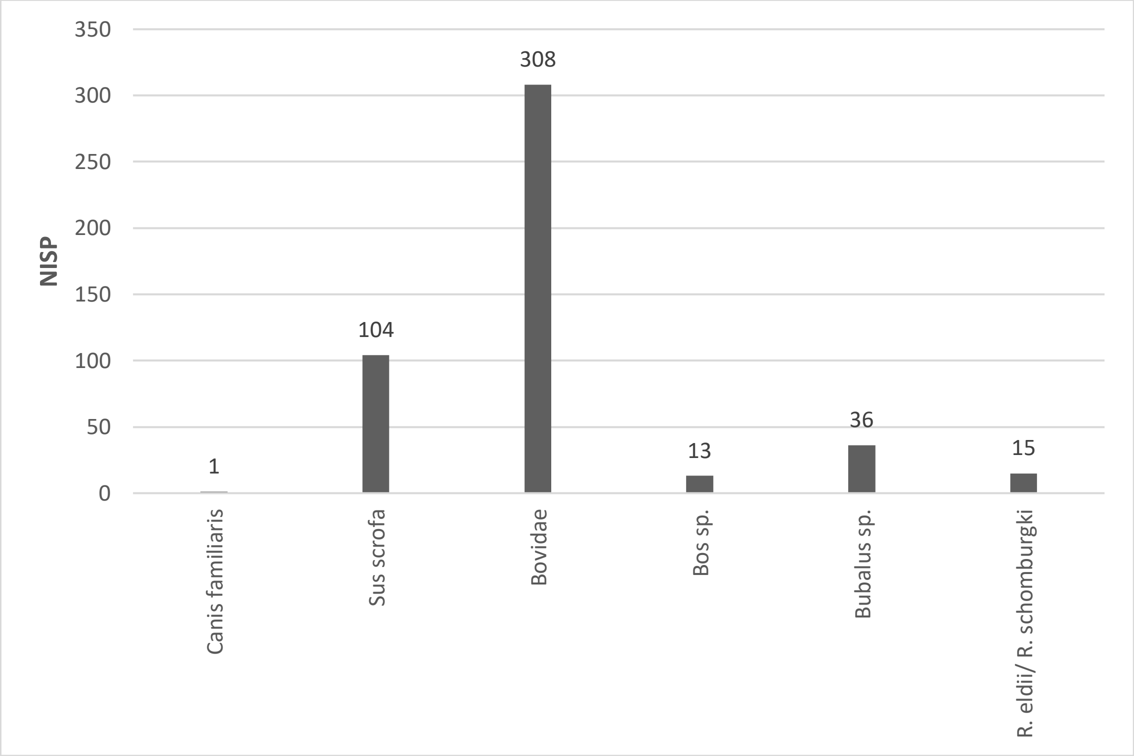


Figure 65: The frequency of NISP in the bone midden feature 1 layer 3 spit 5, K500 at BNW

5.2.10 Canine Burials

Over the course of the excavation two fully articulated dog burials were uncovered. One young dog skeleton was found in excavation unit G104 (Figure 66). The young dog skeleton was in layer 7, which was dated to the Neolithic period. The young dog still had a full set of deciduous teeth and the long bones were unfused or partially fused (Figure 67). A second dog burial was located in excavation unit W200, on the eastern side of the mound (Figure 19). The dog burial was located in layer 5, which has been dated to the Iron Age period. The dog burial in unit W200 contained grave goods, including a whole flat pot and a second, fragmented flat pot (Figure 68). The bones of the dog were all fully fused, and the teeth, especially the incisors and canines, showed advanced signs of wear (Figure 69). Given the wear of the teeth, this indicates an older adult dog. The sex of the dog burial in unit W200 was determined as male from the presence of the baculum bone (Figure 70). A third incomplete disarticulated dog skeleton was also found in excavation unit U200, on the eastern side of the mound (Figure 19). This skeleton was not complete, as the skull, hindlimbs, tarsals, metatarsal, carpals, metacarpals, and phalanx were missing

(Figure 71). This incomplete dog skeleton was located in layer 3, which was dated to the Iron Age period. The bones were from an adult dog, as they were fully fused.

Figure 66: The Neolithic young dog skeleton in excavation unit G104 at BNW (image by Chang, 2008)

Figure 67: The deciduous teeth of the Neolithic young dog in excavation unit G104 at BNW

Figure 68: The Iron Age dog burial in excavation unit W200 at BNW (image by Chang, 2010)

Figure 69: The skull and right mandible of the Iron Age dog burial in excavation unit W200 at BNW

Figure 70: The baculum from the Iron Age dog burial in excavation unit W200 at BNW

Figure 71: The disarticulated dog skeleton in excavation unit U200 at BNW (image by Chang, 2008)

5.2.11 Age at Death Estimates for *Sus*

One hundred and eight pig mandibles from BNW were suitable for use in age at death estimates (Appendix B). All seven age classes for pig were identified at BNW (Figure 72). Five mandibles from BNW were classified as newborn (ca. less than 4 months), with no molars erupted and dp_4 with little to no wear. Thirteen mandibles were infantile (ca. 4 to 6 months), with dp_4 showing slight signs of wear and M_1 erupting or just erupted. The majority of the mandibles (36) were juvenile (ca. 4-6 months), with dp_4 at late stages of wear, and with M_2 just erupting. Thirty-one mandibles were young sub-adults (ca. 12-18 months), with the P_4 erupted and M_2 at early stages of wear. Fifteen were sub-adult (ca. 18-24 months) with the M_3 half erupted. Six mandibles were from adult specimens (ca. 24 to 36 months) with all molars erupted showing medium to late stages of wear. Two mandibles were from older adult animals (ca. over 36 months) with all molars erupted showing late stages of wear. The age at death estimates for pig mandibles by volume (m^3) throughout time at BNW show the change from young sub-adults in the Bronze Age to juveniles in the Iron Age (Figure 73). The Neolithic pig mandibles were predominately a spread of juvenile, young sub-adults, and sub-adult. However, the Neolithic pig mandibles sample was small (n=12). The Bronze Age pig mandibles distribution was centred on young sub-adults and the Iron Age pig mandibles distribution was centred on the juvenile age class.

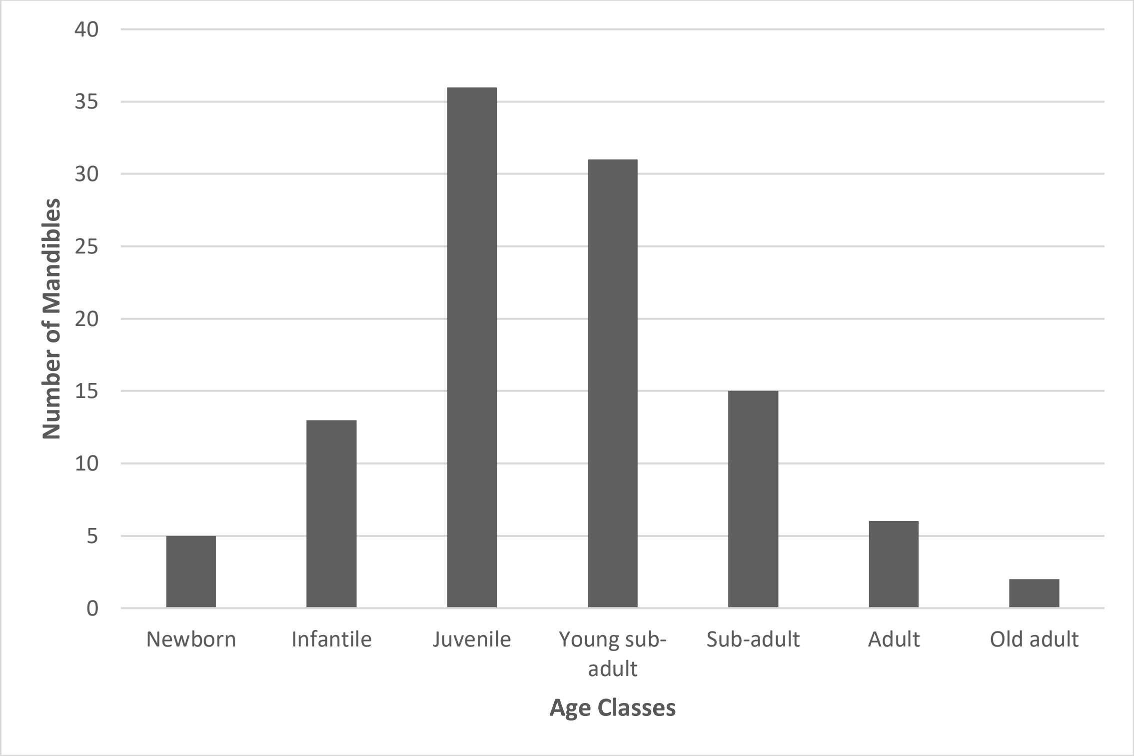


Figure 72: The age at death estimates for pig mandibles from BNW

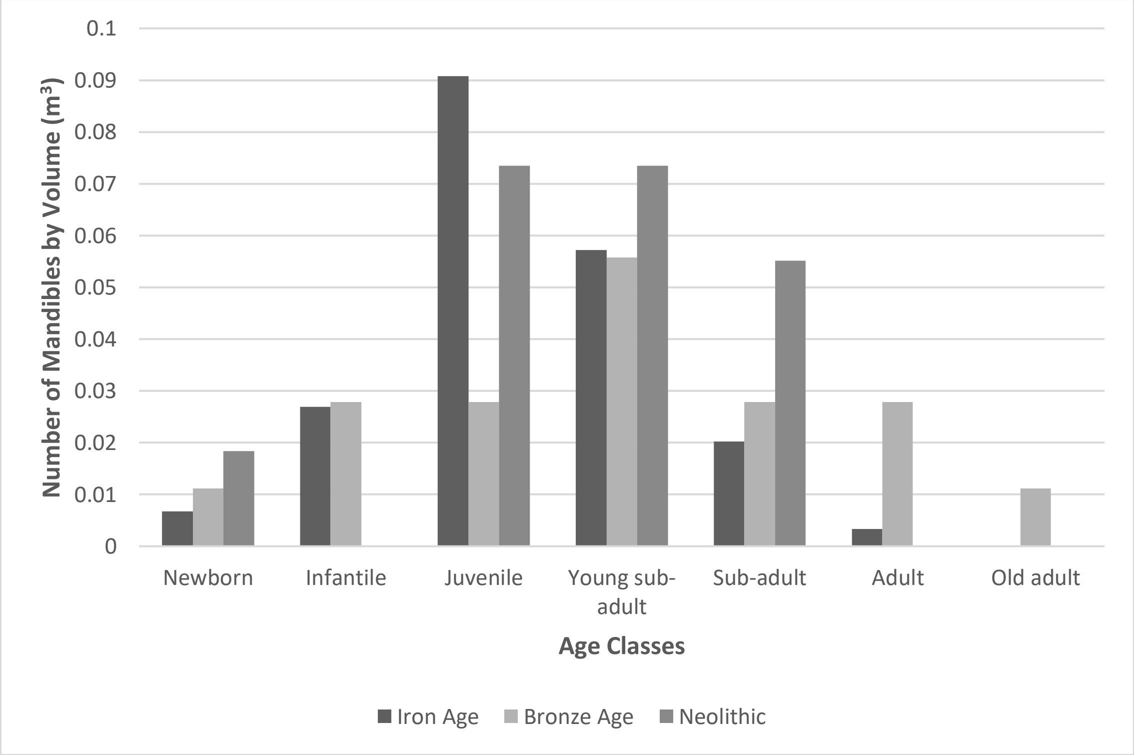


Figure 73: The age at death estimates for pig mandibles by volume (m^3) through time at BNW

5.3 BAN SALAO FAUNAL ANALYSIS

A total of 3045 bone pieces were uncovered during the 2009-10 excavations of square M100 at BSL. Due to fragmentation of the assemblage, 2408 of the pieces lacked the morphological features to identify them taxonomically. The remaining 637 bone pieces were identified into 22 taxonomic groups (Table 9). The taxonomic groups comprised both wild and domestic species, from both terrestrial and aquatic ecosystems. The mammal fauna included dogs, pigs, cattle, water buffalo, gorals**,** and large, medium, and small sized deer. The measurements of pig mandibles were within both the large and small size ranges, and were likely from both wild and domestic examples (Appendix A). No jackal elements were identified from the mandible measurements of the *Canis* genus (Appendix C). Larger mammals, such as rhinoceros and elephant, were absent in the assemblage. The Felidae family, which includes cats, tigers and wild cats, was also absent. The assemblage contained small mammal bones, including mice and rats. The reptilian fauna, comprised turtles and tortoises, included turtles from the soft-shelled family. No large reptiles, such as snake, monitor lizard, and crocodile were identified in the BSL assemblage. Avian fauna were represented by two identified bones from a chicken/ red junglefowl. Five bones were identified as frog from the Amphibian family. Only eight pieces of bone were classified as belonging to fish. The walking catfish was the most commonly identified fish, followed by the climbing perch. One bone piece was identified as belonging to the catfish family, which could be from the walking catfish or an anther species of catfish. Also one bone piece was identified as belonging to snakehead murrel fish.

5.3.1 The Frequency of Identified Taxa (NISP)

The bovids, including water buffalo and cattle, were the most commonly identified animal in the assemblage, making up 60 per cent of the NISP (Figure 74). The ratio of identifiable elements of water buffalo to cattle is 1.4:1. Pig was the second highest taxa represented, at 21 per cent. The deer accounted for eight per cent of NISP, closely followed by the turtle and tortoise at six per cent. The soft-shelled turtle, frog, dog, mice, and rats, and the fish class, each accounted for one per cent of the NISP. The chicken/ red junglefowl, goral, and the small mammal fauna each make up less than one per cent of the NISP.

5.3.2 MNI Estimates

The MNI estimates showed pigs were the highest represented taxon, with four young and six older individuals estimated (Table 9). The bovid was second with nine old individuals. If the bovid MNI estimates included water buffalo then the cattle MNI would be equal to pig, with one young and nine older individuals estimated. The water buffalo had three old individuals, while the cattle one young and one older individual. The sambar deer had one young and two older individuals estimated. Eld's deer and Schomburgk's also had a MNI of three, with three older individuals estimated. The frog, domestic dog and the goral all had two individuals estimated. The rest of the taxa had an MNI estimate of one.

Table 9: NISP and MNI of taxa from all hand collected, dry sieved, and wet sieved samples from all contexts at BSL

Class	**Order**	**Family**	**Taxon**	**Common name**	**NISP**	**NISP (%)**	**MNI**
Amphibian	Anura			Frog	5	0.78	2
Reptilia	Testudines	Geoemydidae/ Platysternidae/ Testudinidae		Box, pond and water turtle/ Big-headed turtle/ Tortoise	40	6.28	1
		Trionychidae		Soft-shelled turtle	3	0.47	1
Aves	Galliformes	Phasianidae	*Gallus gallus*	Chicken/ Red junglefowl	2	0.31	1
Mammalia	Carnivora	Canidae	*Canis* sp(p).	Domestic dog/ Jackal	5	0.78	1
			Canis familiaris	Domestic dog	3	0.47	2
	Artiodactyla	Suidae	*Sus scrofa*	Pig/ Boar	136	21.35	10
		Bovidae		Bovid	345	54.16	9
			Bos sp(p).	Domestic/ Wild Cattle	14	2.2	2
			Bubalus sp(p).	Water buffalo	20	3.14	3
			Naemorhedus sp(p).	Goral	2	0.31	2
		Cervidae		Deer	5	0.78	1
			Rusa unicolor	Sambar deer	10	1.57	3
			Rucervus eldii/ Rucervus schomburgki	Eld's deer/ Schomburgk's deer	26	4.08	3
			Rucervus eldii	Eld's deer	1	0.16	1
			Axis porcinus/ Muntiacus muntjak	Hog deer/ Barking deer	6	0.94	1
Mammalia (small)				Small mammal	2	0.31	1

	Rodentia	Muridae		Mouse and rat	4	0.63	1
Actinopterygii (ray-finned fish)	Siluriformes	Siluridae		Catfish	1	0.16	1
		Clariidae	*Clarias* sp(p).	Walking catfish	4	0.63	1
	Perciformes	Channidae	*Channa striata*	Snakehead murrel	1	0.16	1
		Anabantidae	*Anabas testudineus*	Climbing perch	2	0.31	1

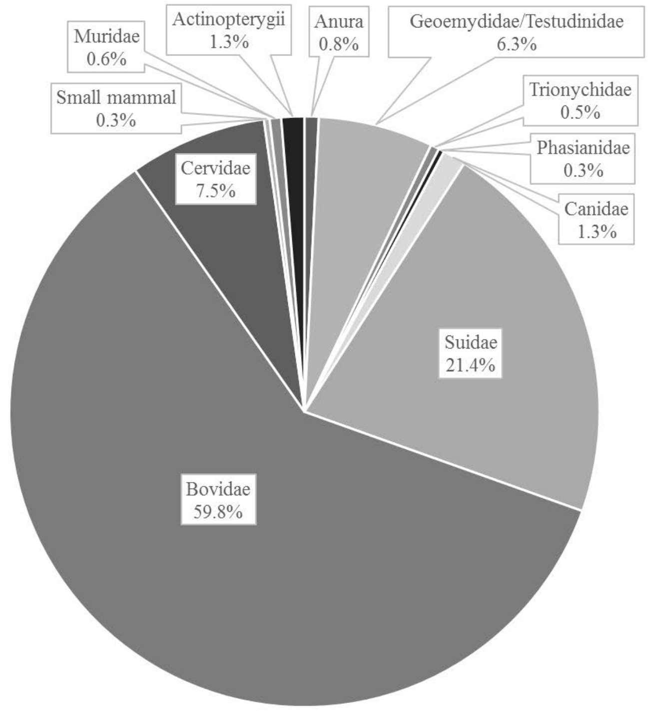


Figure 74: The relative frequency of NISP by family, order, or class level at BSL

5.3.3 Identifying Members of the Bovidae Family

Thirty-four bovid bone elements from the excavation of BSL were used to identify between genera of *Bos* and *Bubalus*. One distal end of a metatarsal was identified as *Bubalus* and one as young *Bos* (Figure 75). Measurement values of *Bubalus* metatarsal distal end measurements were higher than those from modern female specimens from Thailand (Appendix I). The *Bubalus* metatarsal is most likely from a male animal or a wild water buffalo species *Bubalus arnee*. The distal metatarsal from the sub-adult *Bos* was in the fusing state of epiphyseal fusion. The measurements from the metatarsal of the sub-adult *Bos* would likely be greater if the animal was fully mature. However, the measurements from the sub-adult metatarsal were still within the modern range of the distal end of *Bos* (Appendix I). Six magnums were identified as belonging to the *Bos* and *Bubalus* genera from visual inspection and from measurements. Two right and three left magnums were identified as *Bubalus,* and one right magnum as *Bos* (Appendix J).

Figure 75: The distal metatarsal from a *Bubalus* sp. (left) and the distal end metatarsal from a sub-adult *Bos* (right)

Sixteen first phalanges from BSL were used to identify between *Bos* and *Bubalus* (Appendix K, Figure 76). Seven of the 16 first phalanges were identified as *Bubalus* phalanges. The length and proximal width of the seven *Bubalus* phalanges were all at the high end or above range for *Bubalus bubalis* female measurements. It is possible that the phalanges were from wild water buffalo *Bubalus arnee*. However, they could also be from a larger male *Bubalus bubalis*. Nine of the phalanges were identified as *Bos*. Five of the phalanges were within the range of *Bos taurus* measurements. The other four were closer in size to wild cattle species *Bos gaurus* and *Bos javanicus*. With the aid of the comparative collection ten third phalanges were used to identify between *Bos* and *Bubalus*. Seven of the ten phalanges were identified as *Bubalus* and three were *Bos*.

Figure 76: The first fore phalanx from a *Bubalus* sp. (left) and *Bos* sp. (right) from BSL

Two bone elements from the excavation of BSL were identified as the genera *Naemorhedus* (Appendix L). One was a left metacarpal from an adult animal; the other was a left metatarsal from a juvenile animal (Figure 77). The elements were too small to be from the *Capricornis* genara when compared to metacarpals and metatarsals from Mead and Taylor (2005).

Figure 77: The metacarpal from a *Naemorhedus* sp. (left) and the distal end metatarsal from a juvenile *Naemorhedus* sp. (right)

5.3.4 Identifying Members of the Cervidae Family

One antler fragment at BSL was identified as Eld's deer. The Eld's deer antler had both a pedicle and burr present (Figure 78).

Figure 78: Eld's deer antler fragment from BSL

5.3.5 The Frequency of Skeletal Elements from Bovidae, *Sus*, and Cervidae

The identified Bovidae grouped skeletal elements from the Iron Age at BSL show a higher percentage of phalanx and sesamoid elements than other elements (Figure 79). The tarsal and metatarsal, and the upper forelimb elements, were also identified in higher amounts in comparison to other elements. Whereas the carpal and metacarpal, upper hindlimb, and cranial elements were relatively lower in percentage (Figure 79).

The *Sus scrofa* grouped skeletal elements from the Iron Age at BSL displayed a higher percentage of meat-bearing bones, with cranial elements, upper forelimb, and upper hindlimb elements identified in high amounts in comparison to other elements (Figure 80). The tarsal and metatarsal, carpal and metacarpal, and phalanx elements were much lower in percentage (Figure 80).

The Cervidae grouped skeletal elements from the Iron Age at BSL were comprised of a high percentage of tarsal and metatarsal elements (Figure 81). The cranial and upper forelimb elements were also identified in higher amounts. The upper hindlimb elements were lower in percentage in comparison to other elements. The phalanx and sesamoid, and carpal and metacarpal, were much lower in percentage in comparison to other elements (Figure 81).

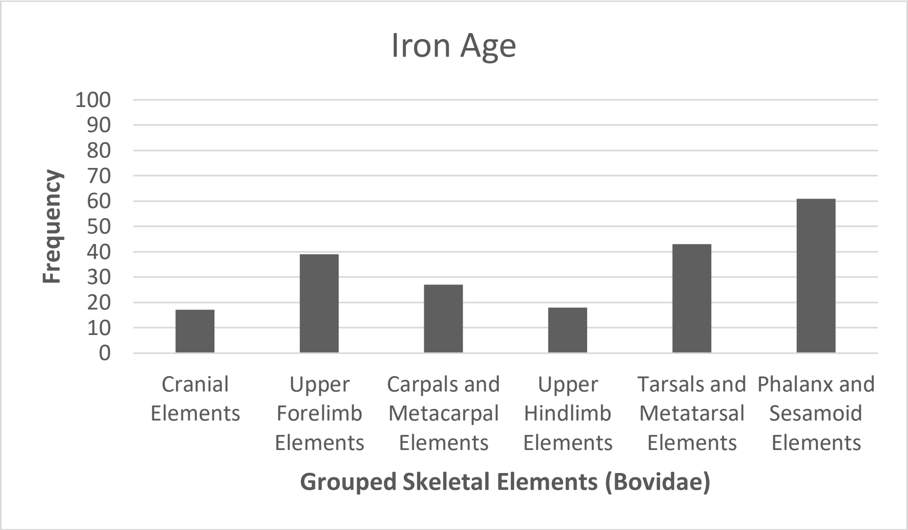


Figure 79: The frequency of Bovidae elements from the cranial, upper forelimb, carpal and metacarpal, upper hindlimb, tarsal and metatarsal, and the phalanx and sesamoid from the Iron Age at BSL

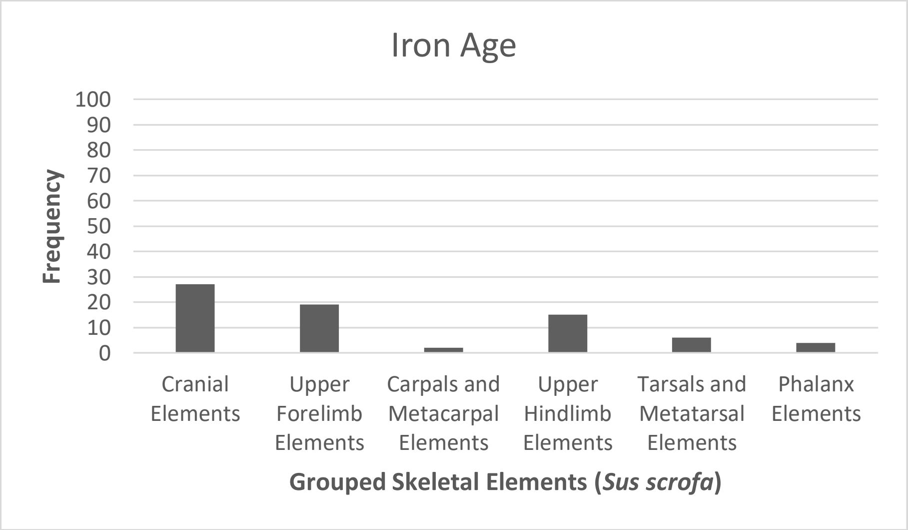


Figure 80: The frequency of *Sus scrofa* elements from the cranial, upper forelimb, carpal and metacarpal, upper hindlimb, tarsal and metatarsal, and phalanx from the Iron Age at BSL

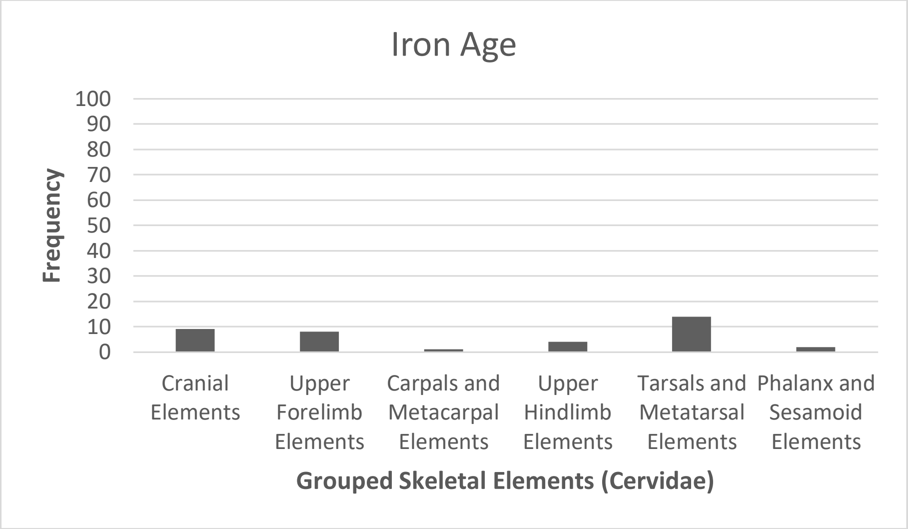


Figure 81: The frequency of Cervidae elements from the cranial, upper forelimb, carpal and metacarpal, upper hindlimb, tarsal and metatarsal, and phalanx from the Iron Age at BSL

5.3.6 NISP by Context

NISP values for the more commonly identified mammals found in general spit, feature, and burial contexts at BSL are presented in Figure 82. Both pig and bovid were found in relatively equal amounts in general spit and feature contexts. Pig remains came from a range of features, including post holes, pits, middens, and pottery concentrations. The majority of bovid remains came from one bone midden feature in layer five. Bone midden features are further analysed in: *5.3.8 The Iron Age bone midden feature* in this chapter. Only one burial context was discovered at BSL. Thus the NISP value was low due to only a smaller amount of sediment being removed from burial contexts.

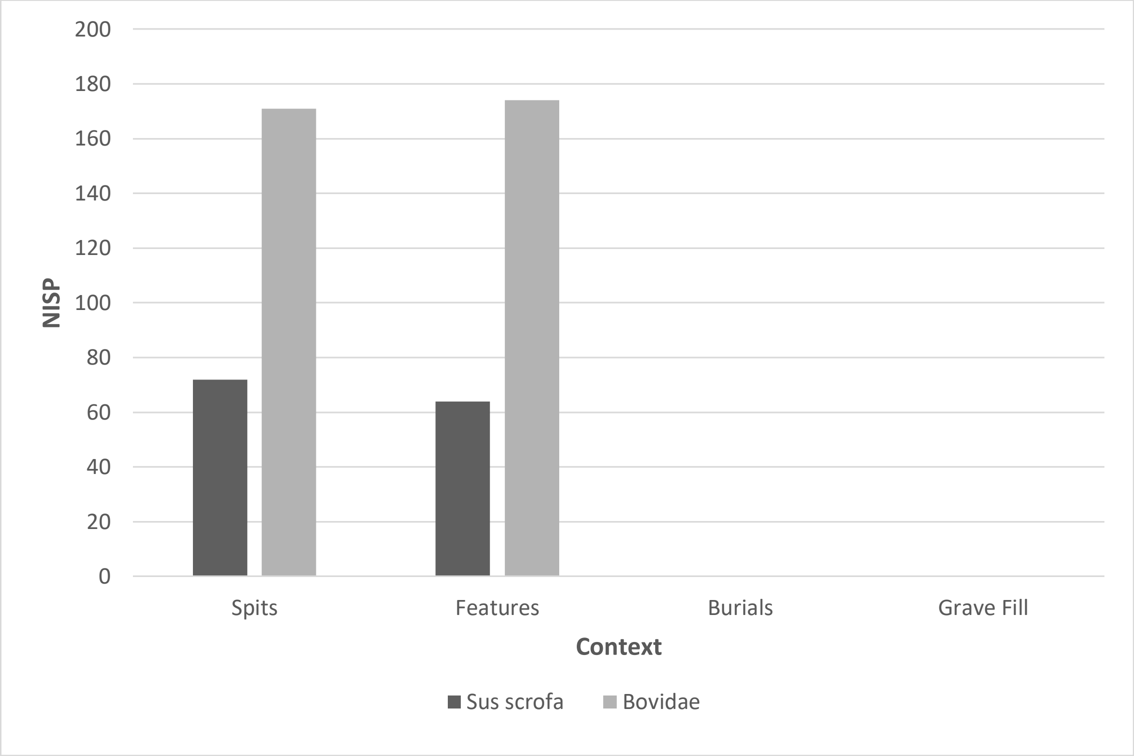


Figure 82: The NISP value for the more frequently identified taxa by context type from all periods at BSL

5.3.7 Frequency of NISP by Volume (m^3)

The frequency of NISP by volume (m^3) from the hand collected and dry sieved data and flotation sample from Iron Age contexts at BSL are presented in Figure 83 and Figure 84. No bone specimens were recovered from the Modern period contexts. Only two Bovidae NISP (0.461 NISP by m^3) from the hand collected and dry sieved data were identified in Historic period contexts. The BSL Iron Age hand collected and dry sieved data shows bovid was the highest represented taxon by volume, followed by pig (Figure 85). The NISP by volume from the flotation sample in the Iron Age were noticeably lower than the Iron Age at BNW. Pig was the highest represented taxon by volume from the flotation sample, followed by frog (Figure 84).

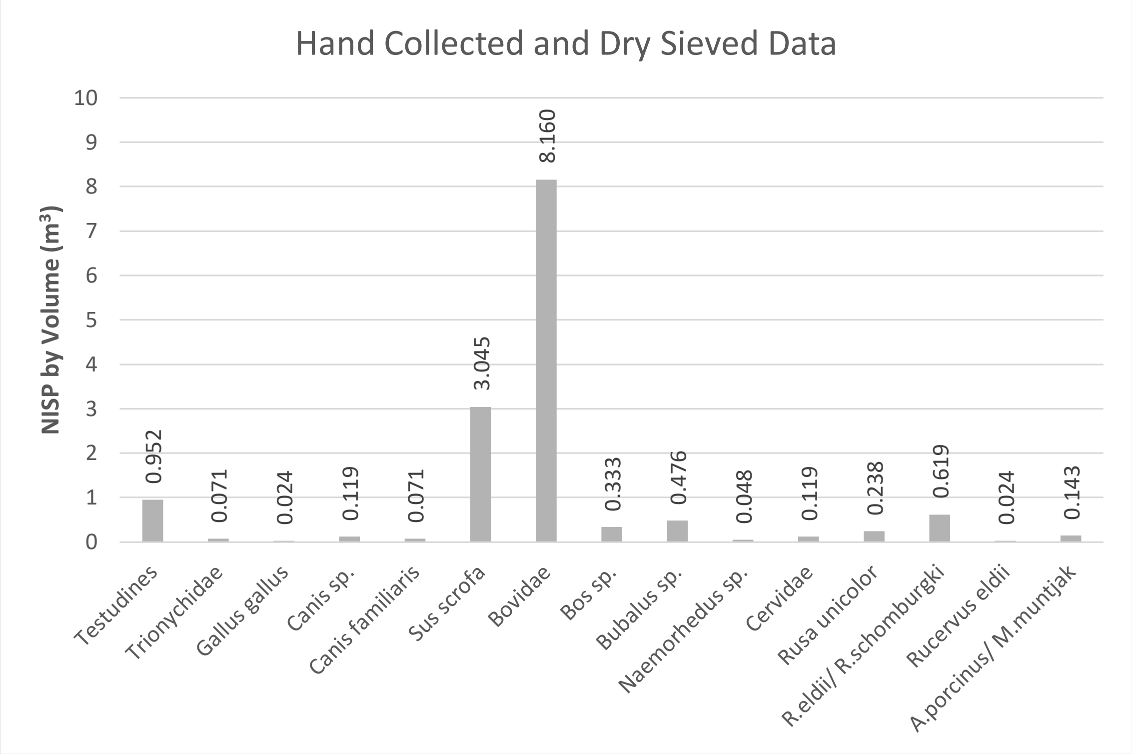


Figure 83: The frequency of NISP by volume (m^3) from hand collected and dry sieved data in the Iron Age at BSL

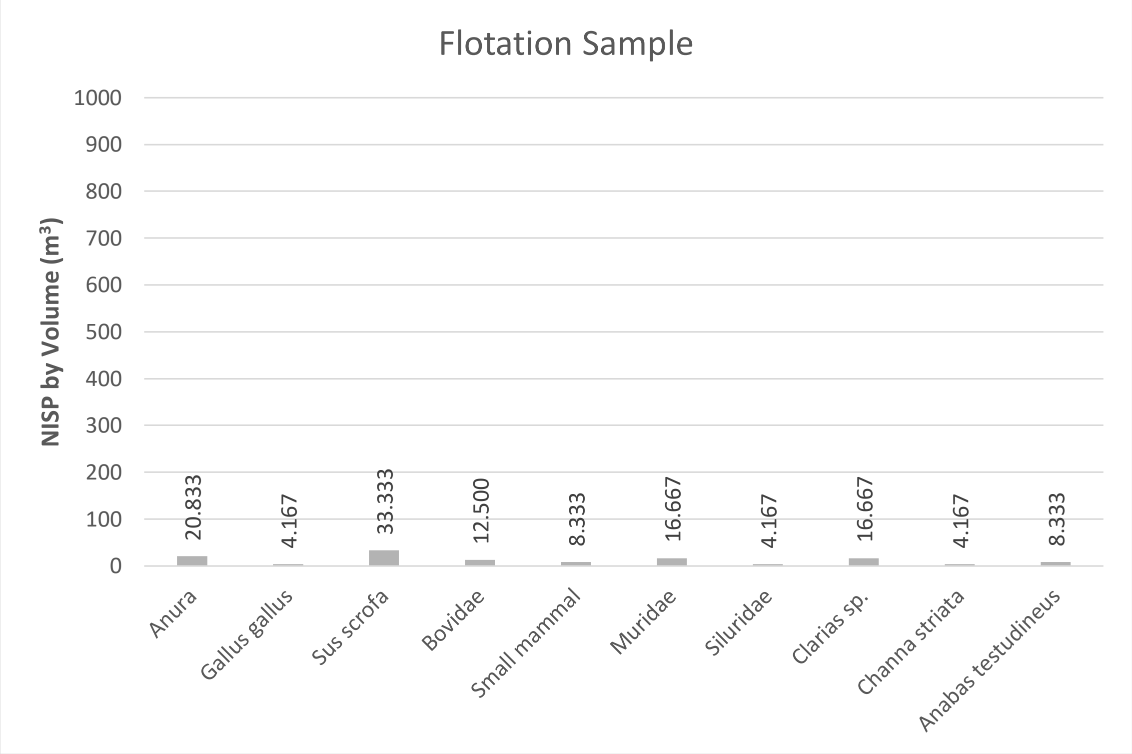


Figure 84: The frequency of NISP by volume (m^3) from the flotation sample in the Iron Age at BSL

5.3.8 The Iron Age Bone Midden Feature

The majority of the bone elements found at BSL were located in an Iron Age bone midden feature in layer five (Figure 85). The bone midden feature at BSL contained a high amount of bovid bones (Figure 86). The bovid bones in the feature accounted for 66 per cent of the total bones found in the feature. The ratio of identifiable elements of water buffalo to cattle in the feature favoured water buffalo. The ratio of water buffalo to cattle in the feature in the unit was 2:1. Similar Iron Age bone midden features were uncovered at BNW. The result of the bone midden features from BNW are presented under the heading *5.2.9 The Iron Age Bone Midden Features*.

Figure 85: The Iron Age bone midden feature in layer 5 at BSL, facing south (image by Chang, 2010)

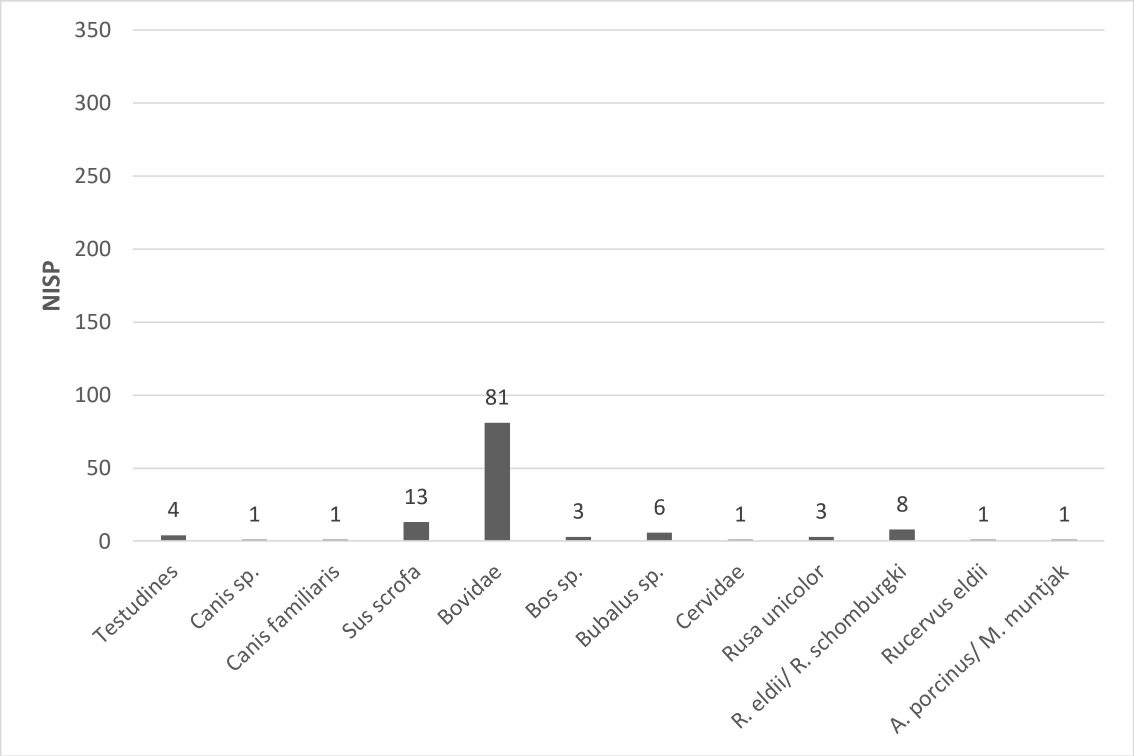


Figure 86: The distribution of NISP in the bone midden feature 187 layer 5 Spit 1, at BSL

5.3.9 Age at Death Estimates for *Sus*

Eight pig mandibles from BSL were suitable for use in age at death estimates (Appendix B). Four out of the seven were juvenile (ca. 4-6 months) with dp_4 at late stages of wear, and with M_2 just erupting. Three mandibles were young sub-adults (ca. 12-18 months), with the P_4 erupted and M_2 at early stages of wear (Figure 87). The remaining mandible was a sub-adult (ca. 18-24 months) with the M_3 half erupted.

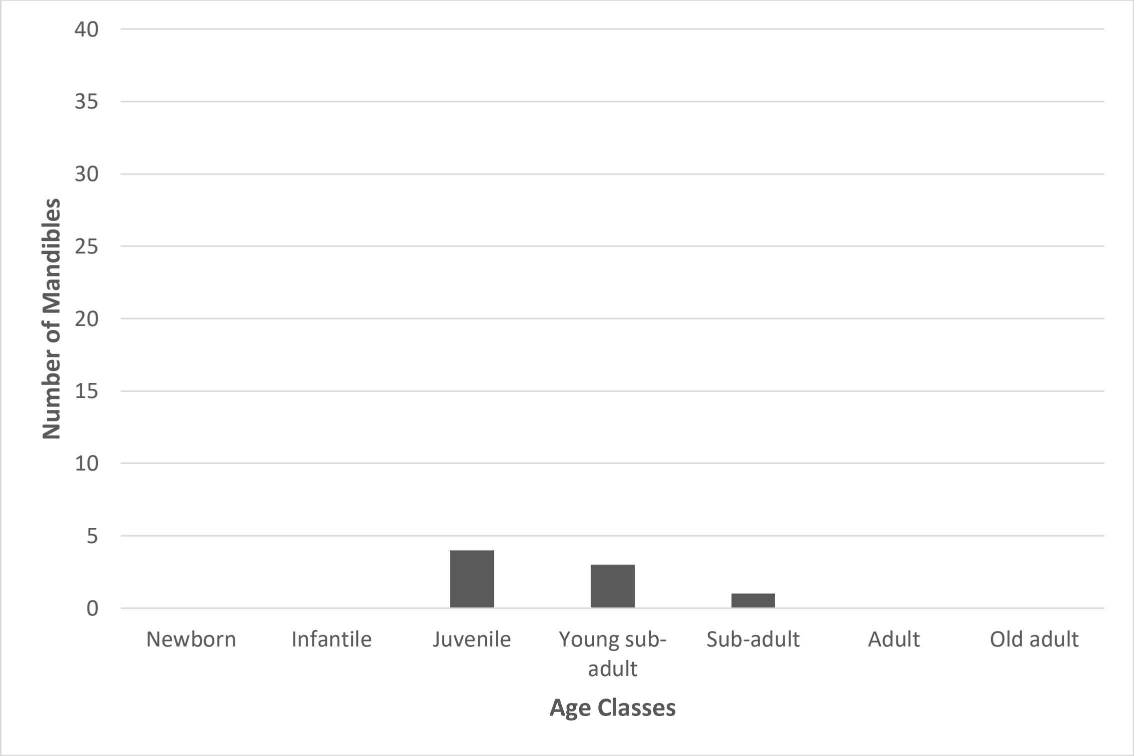


Figure 87: The age at death estimates for *Sus* sp. mandibles from BSL

5.4 NONG HUA RAET FAUNAL ANALYSIS

During the 2011 excavation at NHR a total of 2296 bone pieces were uncovered at the site. Due to fragmentation of the assemblage 1942 of the pieces lacked the morphological features used to identify them taxonomically. The remaining 354 bone pieces were identified into 16 taxonomic groups (Table 10). The faunal assemblage at NHR contained both wild and domestic species, from terrestrial and aquatic ecosystems. The mammal fauna included dogs, pigs, cattle, water buffalo, medium and small sized deer. The measurements of pig mandibles were consistent with the domestic range (Appendix A). The larger sambar deer species was absent in the assemblage. Large mammals, such as rhinoceros and elephants, were also absent in the assemblage, as were tigers, wild cats and domestic cats. The assemblage contained small mammal bones, which were only able to be identified to a class level. The reptilian fauna was represented by turtles and tortoises. No soft-shelled turtles or other reptiles, such as, snake, monitor lizard, and crocodile, were identified in the assemblage. Avian fauna was limited to one individual bone from a chicken/ red junglefowl. Likewise, Amphibian fauna comprised one individual frog bone. Four species of fish were identified, including the walking catfish, Asian swamp eel, snakehead murrel, and climbing perch.

5.4.1 The Frequency of Identified Taxa (NISP)

The bovid, including water buffalo and cattle, were the highest represented specimen in the assemblage, constituting 47 per cent of the NISP (Figure 88). The ratio of identifiable elements of water buffalo to cattle was 2.2:1. Pig was the second highest taxa, with 26 per cent of the NISP, followed by deer with 13 per cent. The fish class accounted for eight per cent of the NISP. The turtle and tortoise made up three per cent, and small mammal fauna one per cent. The dog, frog, chicken/ red junglefowl specimen each accounted for less than one per cent of the NISP.

5.4.2 MNI Estimates

The MNI estimates showed a different result, with pigs being the highest represented Family, with three young and four older individuals estimated. The bovid was second with one young and four older individuals. The Bovidae MNI estimates would not change if the water buffalo and cattle elements were included. The walking catfish had four individuals estimated. The Eld's and Schomburgk's deer included one young and two older individuals. The snakehead murrel and the climbing perch both had two individuals. The rest of the taxa had a MNI estimate of one.

Table 10: NISP and MNI of taxa from all hand collected, dry sieved, and wet sieved samples from all contexts at NHR

Class	Order	Family	Taxon	Common name	NISP	NISP %	MNI
Amphibian	Anura			Frog	1	0.28	1
Reptilia	Testudines	Geoemydidae/ Platysternidae/ Testudinidae		Box, pond and water turtle/ Big-headed turtle/ Tortoise	15	4.24	1
Aves	Galliformes	Phasianidae	*Gallus gallus*	Chicken/ Red junglefowl	1	0.28	1
Mammalia	Carnivora	Canidae	*Canis* sp(p).	Domestic dog/ Jackal	3	0.85	1
	Artiodactyla	Suidae	*Sus scrofa*	Pig/ Boar	91	25.71	7
		Bovidae		Bovid	153	43.22	5
			Bos sp(p).	Domestic/ Wild Cattle	4	1.13	1
			Bubalus sp(p).	Water buffalo	9	2.54	2
		Cervidae		Deer	1	0.28	1
			Rucervus eldii/ Rucervus schomburgki	Eld's deer/ Schomburgk's deer	38	10.73	3
			Axis porcinus/ Muntiacus muntjak	Hog deer/ Barking deer	6	1.69	1
Mammalia (small)				Small mammal	5	1.41	1
Actinopterygii (ray-finned fish)	Siluriformes	Clariidae	*Clarias* sp(p).	Walking catfish	14	3.95	4
	Synbranchiformes	Synbranchidae	*Monopterus albus*	Asian swamp eel	1	0.28	1
	Perciformes	Channidae	*Channa striata*	Snakehead murrel	5	1.41	2
		Anabantidae	*Anabas testudineus*	Climbing perch	7	1.98	2

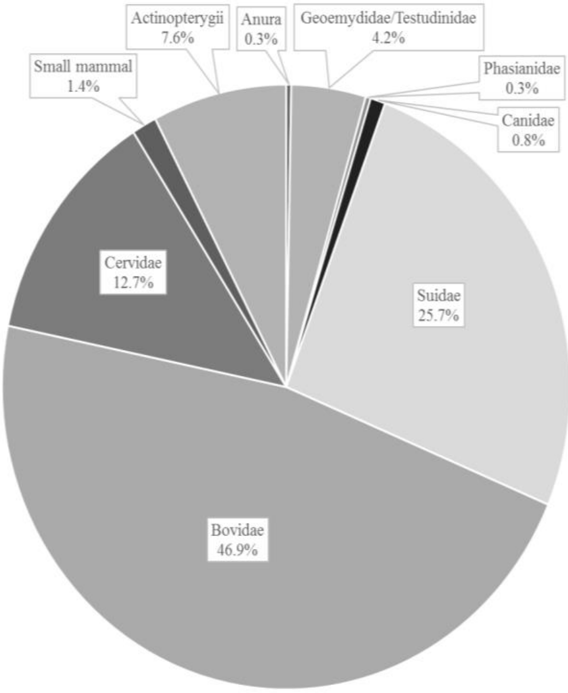


Figure 88: The relative frequency of NISP by family, order, or class level at NHR

5.4.3 Identifying Members of the Bovidae Family

Thirteen bone elements from the excavation of NHR were used to identify between genera of *Bos* and *Bubalus*. Two right metacarpals were identified as *Bubalus* from visual inspection and from measurements of the proximal and distal ends, which were compared to modern day examples of *Bubalus bubalis* from Thailand (Appendix M). Three left distal end metatarsals were identified from the excavation of NHR. On visual inspection, and with the aid of the comparative collection, one of the three metatarsal resembled *Bos* and one *Bubalus* (Figure 89). The third was heavily concreted, making visual inspection difficult. The measurements of the distal ends of the metatarsals confirmed that one metatarsal was *Bos,* the second *Bubalus, and* the third concreted specimen also *Bubalus* (Appendix M). One right magnum was identified as *Bos,* as the magnums maximum width was longer than its maximum depth (Appendix N). The magnum under question was also larger than the *Bos taurus* measurements and the *Bos taurus* magnum in the comparative collection. It is likely that the magnum is from one of the wild cattle species *Bos gaurus*, *Bos javanicus*, or *Bos sauveli*.

Figure 89: A left distal end metatarsal from a *Bubalus* sp. (left) and a left distal end metatarsal from a *Bos* sp. (right) from NHR

Six first phalanges were used to identify between *Bos* and *Bubalus* (Appendix O). Four were classified as *Bubalus* from morphology and measurements. One of the four *Bubalus* phalanges was above the range for *Bubalus bubalis* females, and measured 81.68mm in length (Figure 90). It is possible that this phalanx is from a wild water buffalo, *Bubalus arnee*. However, this could also derive from a larger male *Bubalus bubalis*. Two first phalanges were classified as *Bos*. Both specimens had an irregular ridge on the posterior distal articular surface, which is present in *Bos*. A third phalanx, recovered from the general spit of layer 3 spit 5, was identified as *Bubalus*, with the aid of the comparative collection.

Figure 90: The first fore phalanx from a *Bubalus* sp. (left) and *Bos* sp. (right) from NHR

5.4.4 The Frequency of Skeletal Elements from Bovidae, *Sus*, and Cervidae

The identified Bovidae grouped skeletal elements from the Iron Age at NHR show a higher percentage of phalanx and sesamoid elements than other elements (Figure 91). The carpal and metacarpal, and upper hindlimb, were also identified in high amounts in comparison to other elements. The tarsal and metatarsal, and the upper forelimb elements, were relatively lower in percentage (Figure 79). The identified cranial elements were much lower in percentage in comparison to other elements (Figure 91).

The *Sus scrofa* grouped skeletal elements from the Iron Age at NHR displayed a higher percentage of meat-bearing bones with cranial elements and upper forelimb identified in high amounts in comparison to other elements (Figure 92). The upper hindlimb elements were also identified in high amounts. The tarsal and metatarsal, carpal and metacarpal, and phalanx elements were much lower in percentage in comparison to other elements (Figure 92).

The Cervidae grouped skeletal elements from the Iron Age at NHR displayed a high percentage of cranial and tarsal, and metatarsal elements (Figure 93). The upper forelimb, and phalanx and sesamoid were lower in percentage in comparison to other elements. The upper hindlimb element, and carpal and metacarpal, were much lower in percentage in comparison to other elements (Figure 93).

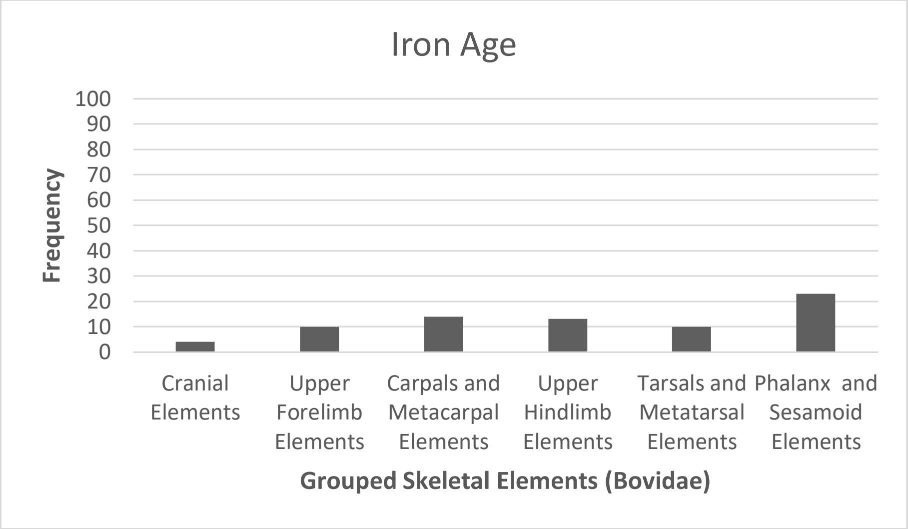


Figure 91: The frequency of Bovidae elements from the cranial, upper forelimb, carpal and metacarpals, upper hindlimb, tarsal and metatarsals, and the phalanx and sesamoid from the Iron Age at NHR

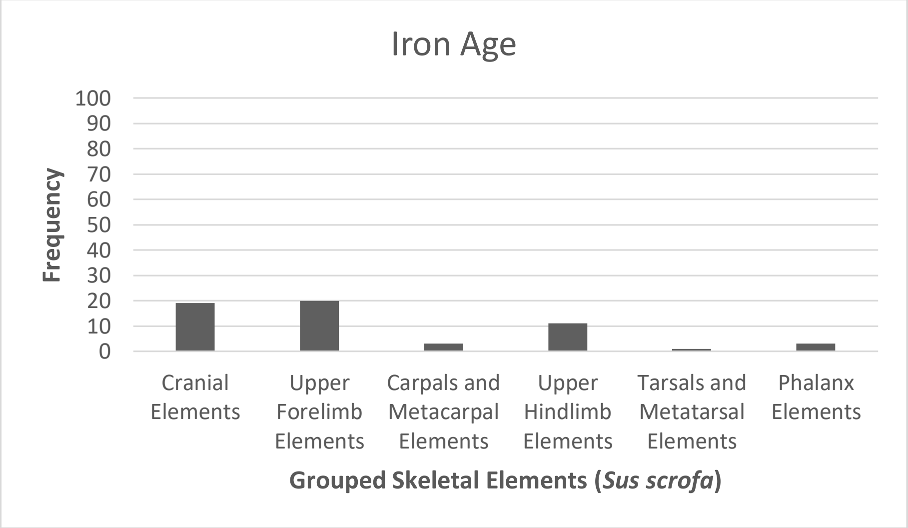


Figure 92: The frequency of *Sus scrofa* elements from the cranial, upper forelimb, carpal and metacarpals, upper hindlimb, tarsal and metatarsals, and phalanx from the Iron Age at NHR

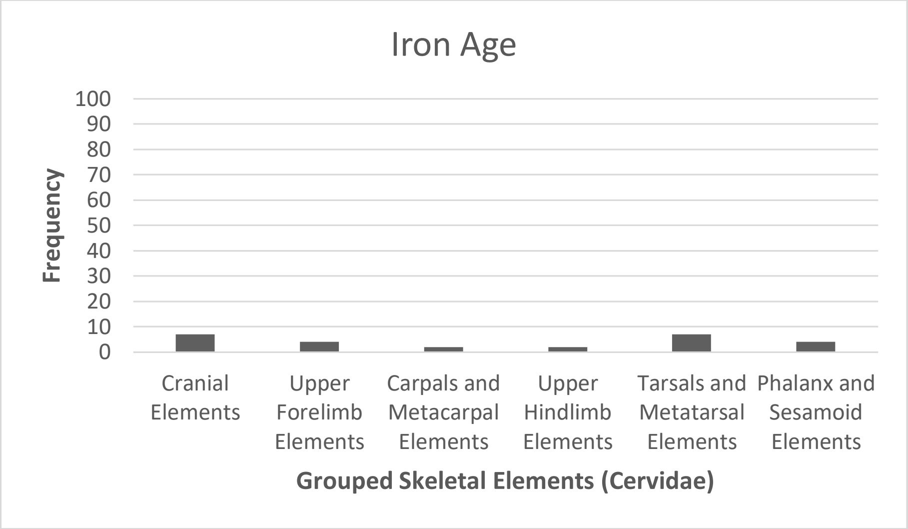


Figure 93: The frequency of Cervidae elements from the cranial, upper forelimb, carpal and metacarpals, upper hindlimb, tarsal and metatarsals, and phalanx from the Iron Age at NHR

5.4.5 NISP by Context

NISP values for the more commonly identified mammals found in general spit and feature at NHR are presented in Figure 94. No burial context was discovered at NHR. Pig remains were found in features more often than in general spit contexts at NHR (Figure 94). Pig remains came from a range of features, including post holes, pits, and pottery concentrations. The majority of bovid remains came from general spit contexts at NHR. The bovid remains from features came from a range of features including post holes, pits, and pottery concentrations.

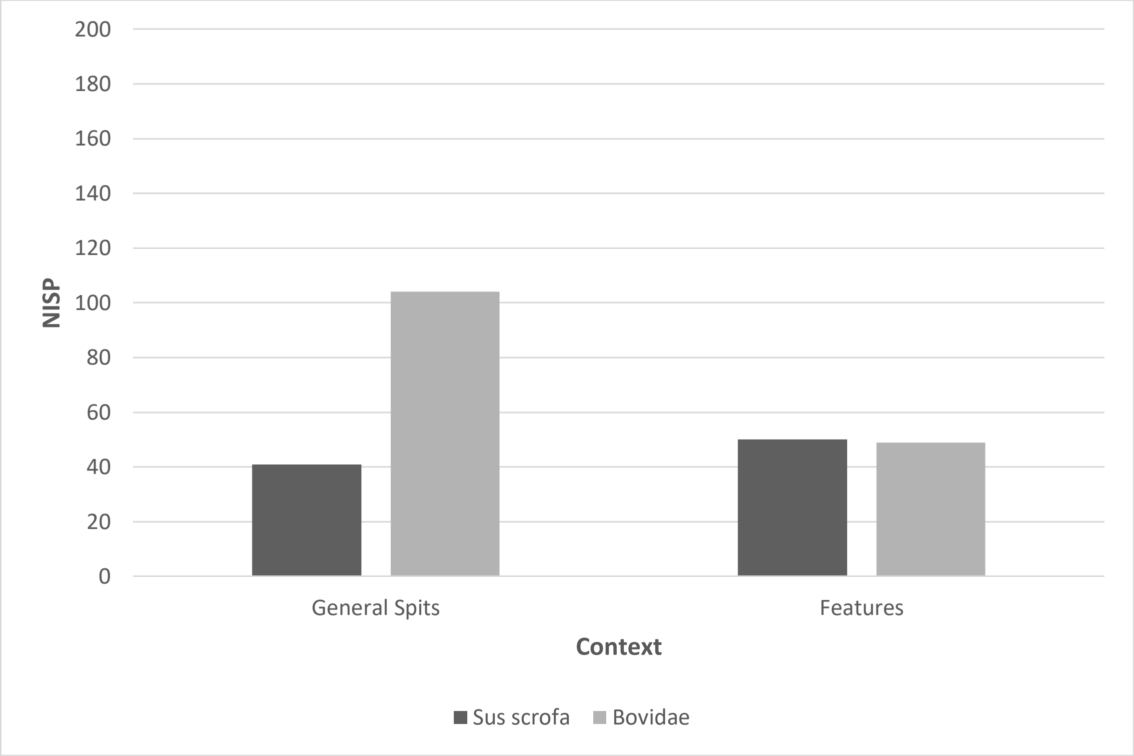


Figure 94: The NISP value for the more frequently identified taxa by context type from all periods at NHR

5.4.6 Frequency of NISP by Volume (m^3)

The frequency of NISP by volume (m^3) from the hand collected and dry sieved data and the flotation sample from the Historic and Iron Age contexts at NHR are presented in Figure 100, Figure 96, and, Figure 97. Only one specimen of Bovidae (0.09 NISP by m^3) and one specimen of Testudines (0.09 NISP by m^3) was recovered in Modern contexts from the hand collected and dry sieved data. The NHR Historic period from hand collected and dry sieved data shows bovid was the highest represented taxon by volume (Figure 95). However, the data size is small for the Historic period and no specimens were identified from the flotation sample. The NHR Iron Age hand collected and dry sieved data shows bovid was the highest represented taxon by volume, followed by pig (Figure 96). The NISP by volume from the flotation sample in the Iron Age was noticeably lower than the Iron Age at BNW. The walking catfish was the highest represented taxon by volume from the flotation sample, followed by climbing perch (Figure 97).

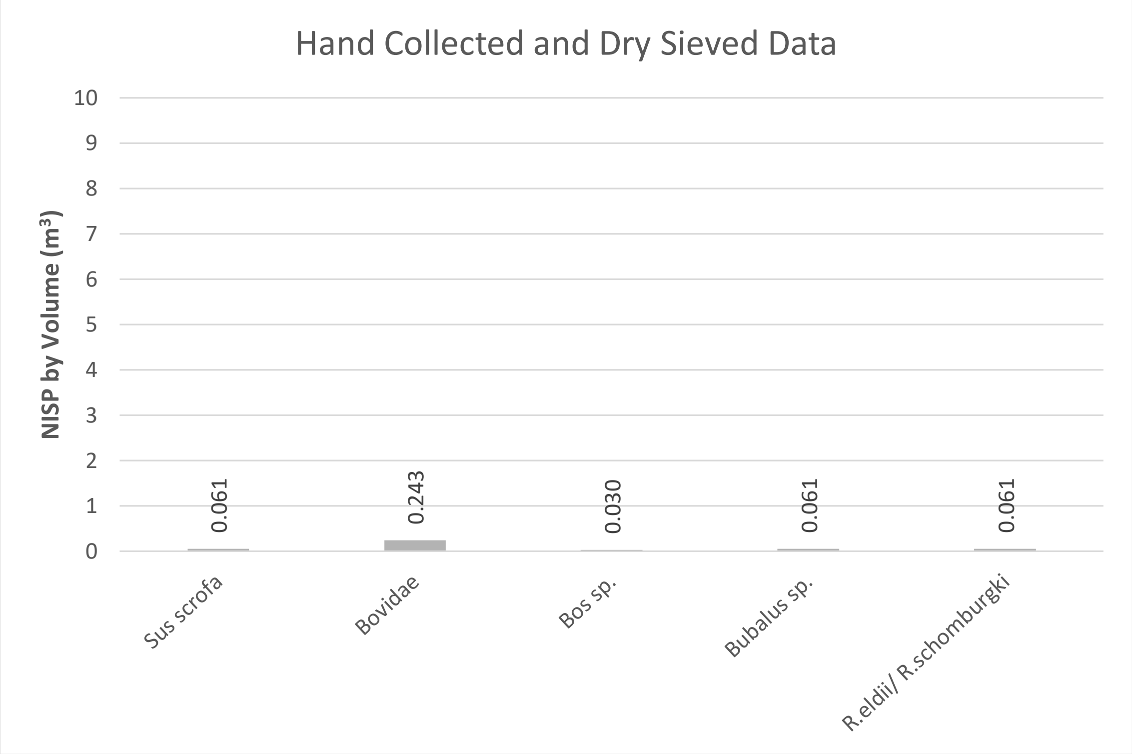


Figure 95: The frequency of NISP by volume (m^3) from hand collected and dry sieved data in the Historic period at NHR

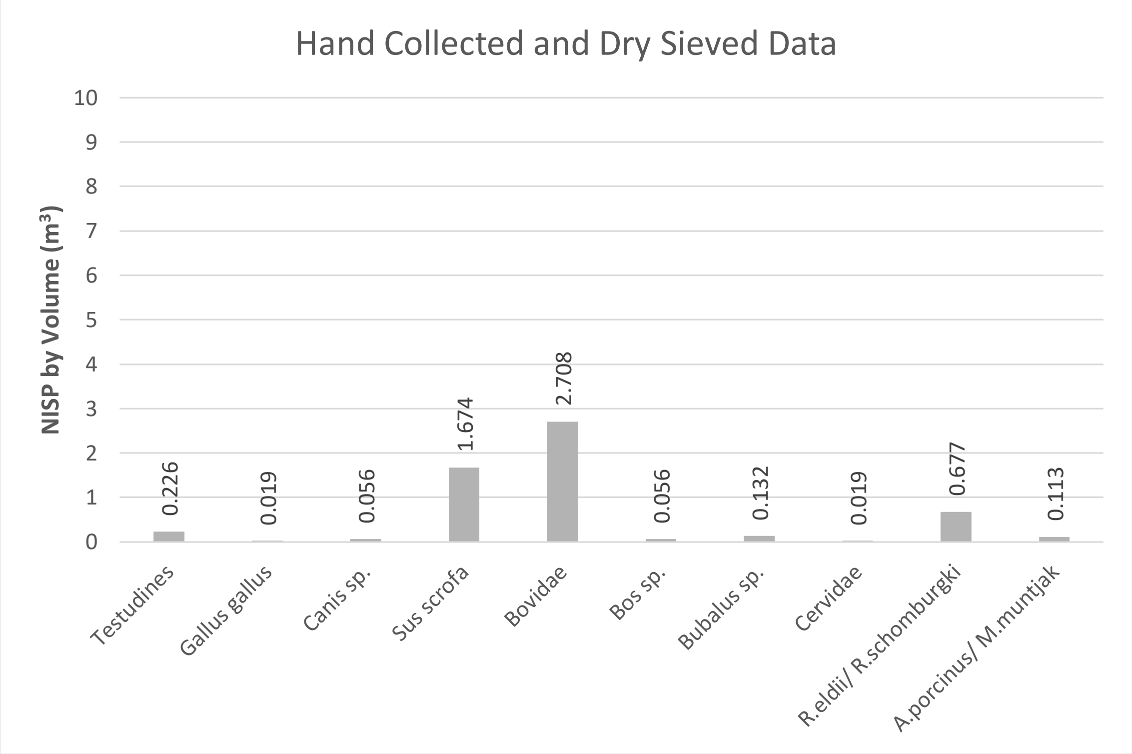


Figure 96: The frequency of NISP by volume (m^3) from hand collected and dry sieved data in the Iron Age at NHR

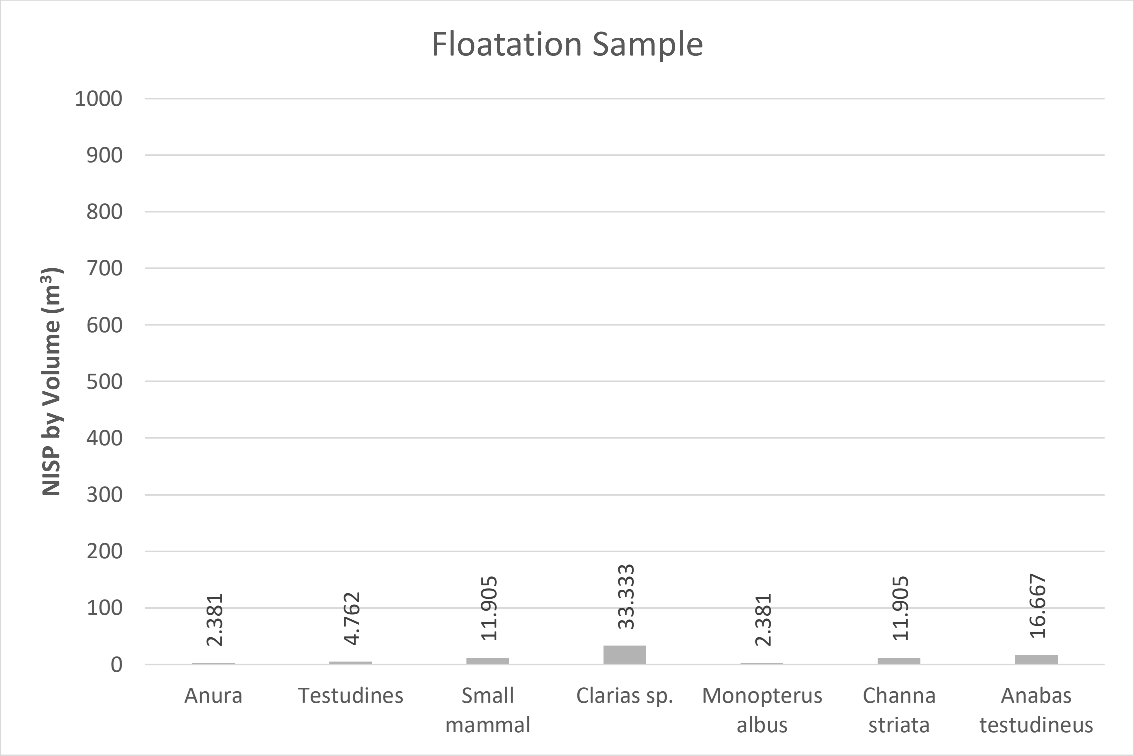


Figure 97: The frequency of NISP by volume (m^3) from the flotation sample in the Iron Age at NHR

5.4.7 Age at Death Estimates for *Sus*

Four pig mandibles from NHR were suitable for use in age at death estimates (Appendix B). Out of the four, three were infantile (ca. 4-6 months), with dp_4 at early stages of wear and M_1 just erupting or in the first stages of wear (Figure 98). The other mandible was a young sub-adult (ca. 12-18 months) with the P_4 erupted.

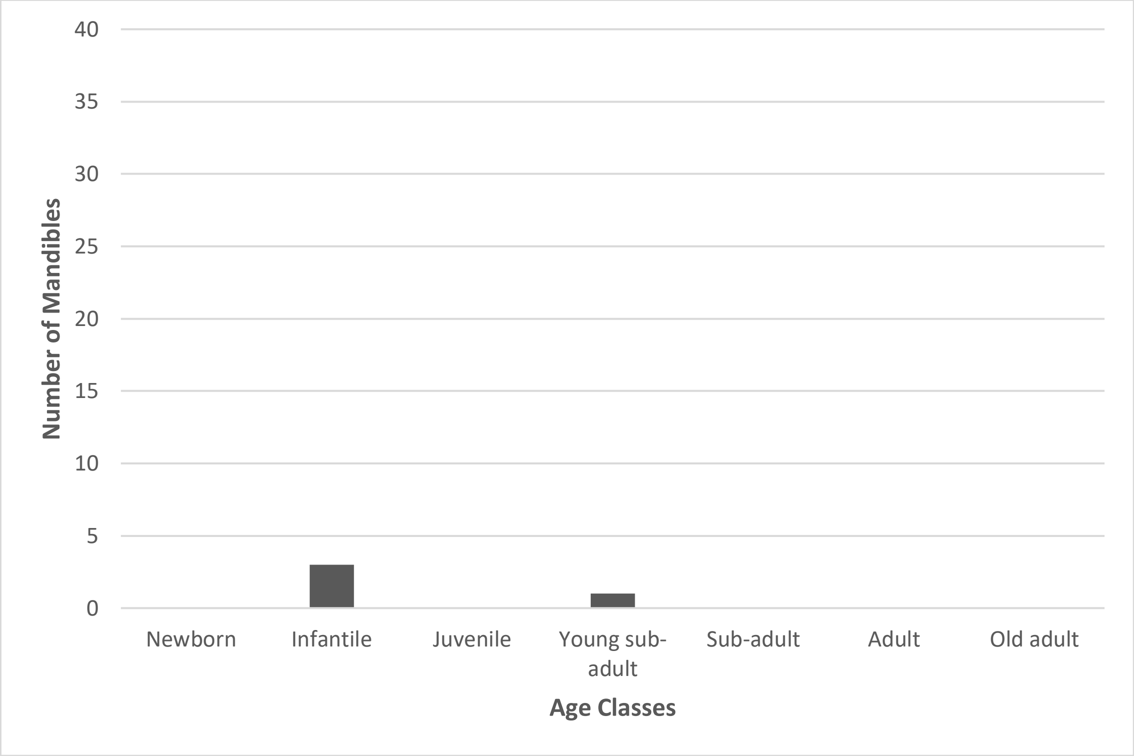


Figure 98: The age at death estimates for *Sus* sp. mandibles from NHR

5.5 CHAPTER SUMMARY

The results from the identification and analysis of vertebrate faunal remains from the prehistoric sites of BNW, BSL, and NHR in the Upper Mun River Valley, are extensive. The main observations of the results are:

- The animal remains at all three sites were fragmented, with remains from the middle and lower layers containing mineral concretions adhered to the surface of the bones
- At BNW pig was the most commonly found mammal followed by bovid, although fish remains outnumbered that of both pig and bovid
- At sites of BSL and NHR bovid remains made up the majority of the assemblage, with pig being the second most commonly identified animal
- Only a small number of aquatic resources such as turtle and fish were identified at BSL and NHR
- Mice and rats were found in high amounts only at BNW

- At all three sites the Eld's and Schomburgk's deer were found in greater amounts compared to other deer species
- At BNW the most commonly identified mammals were found primarily in general spit and feature contexts, and the most commonly identified fish came from general spit, feature, and grave fill
- The frequency of skeletal elements (cranial, forelimb, carpal and metacarpal, hindlimb, tarsal and metatarsal, and phalanx) from bovid, pig, and deer families show no notable difference through time at BNW, or between the three sites when the Iron Age contexts are compared
- The frequency of NISP by volume (m^3) in the hand collected and dry sieved data through time at BNW suggests a change in subsistence strategy from wild resources such as deer and turtle/ tortoise towards domestic animals such as pig and bovid, from the Neolithic to the Iron Age. However fish remains from the wet sieve sample at BNW were prevalent throughout all time periods
- All seven age classes for pig, from newborn to old adult, were identified at BNW in the death estimates for pigs, whereas only three age classes were identified at BSL and two at NHR. However, the sample size at the latter two sites was much smaller
- The age at death estimates for pig mandibles by volume (m^3) throughout time at BNW shows the shift from young sub-adults mandibles in the Bronze Age to juveniles in the Iron Age

Chapter 6: Discussion

This chapter elaborates on the findings from the results in chapter five in order to address the aims of this thesis. The differences in the faunal remains between the three sites are discussed within a framework of subsistence strategies. The changes to subsistence strategies over time are also discussed. The importance of animals such as pig, cattle, and deer for everyday subsistence, and for use in ritual and seasonal feasting within a community, is explored in this chapter. Seasonal hunting practices and the use of traps for hunting and fishing in prehistory, against a background of contemporary culture in northeast Thailand, is considered. This chapter ends with a section of further work that would be beneficial to zooarchaeological research in northeast Thailand and the broader Southeast Asian region.

6.1 SUBSISTENCE STRATEGIES BETWEEN THE THREE SITES

The frequency of NISP by volume (m^3) in the hand collected and dry sieved data at both BSL and NHR had a majority of bovid remains, followed by pig. Whereas at BNW pig was the highest Iron Age NISP by volume (m^3) in the hand collected and dry sieved data, followed by bovid. Fish was only found in small volumes at BSL and NHR. At BNW fish were found in high numbers in all contexts. Other aquatic resources, such as turtle, were also found in high volumes at BNW, and moderately low volumes at BSL and NHR. At all three sites the Eld's and Schomburgk's deer were found in greater volumes compared to other deer species.

6.1.1 Domestic Animals

The frequency of pig bones were high at all three sites, with pig bone fragments outnumbering all other mammals at BNW. Kijngam (2010, p. 197) suggests that domestic pigs, *Sus scrofa domesticus*, were more than likely to have been raised at the site of BNW from the Neolithic period through to the Iron Age. DNA research by Larson et al. (2007) has identified mainland Southeast Asian pigs as the ancestors of pigs transported by people to island Southeast Asia and into the Pacific. Biometrical analysis of pig molars from archaeological sites in Southwest Asia, Europe, China, and Japan suggests a long drawn out domestication process in these regions (Dobney et al., 2008). However, tracing the origin of domestic pigs in mainland Southeast Asia is still the subject of ongoing research.

The results from this thesis show the frequency of pig elements at all sites displayed a disproportionate quantity of cranial, upper forelimb, and upper hindlimb elements in comparison to the carpal and metacarpal, tarsal and metatarsal, and phalanx elements. This analysis was undertaken to investigate if pigs were raised on site or butchered offsite, and traded or brought from another site. A disproportionate amount of a specific element could show the transport of portions of a butchery animal from an offsite location (Reitz & Wing, 2001, p. 225). However, this disproportionate quantity of upper forelimb and upper hindlimb elements is more likely due to the fragmentation of these large elements, and thus being counted more than once. At both BSL and NHR the carpal and metacarpal, tarsal and metatarsal, and phalanx elements were found in low numbers. At this stage it is unknown if pigs were raised at these sites or brought from another site to BSL and NHR, with a preference for the meatier cranial, upper forelimb, and upper hindlimb elements. This more likely depended on whether pigs were being used for feasting events or everyday consumption. The age at death estimates support the idea that pigs were raised or butchered offsite at BSL and NHR, with only sub-adult, young sub-adult, and juvenile pigs at BSL, and young sub-adults and infantile pigs at NHR. If domestic animals are produced and consumed at a site a wide range of ages would be present (Reitz & Wing, 2001, p. 192). However, the sample size was small at BSL and NHR. The sample size was much larger at BNW, due to more excavation units and more pig elements being uncovered.

At BNW every age class was observed, suggesting that pigs were produced and consumed at the site. The age at death estimates for pig mandibles through time by volume (m^3) at BNW showed a trend towards juvenile animals in the Iron Age (Figure 73). This could be an indication of the intensification of hunting at the site, as hunting pressure is placed on the population, younger animal are hunted before they have a chance to reach maturity (Benecke, 1993). However, a cluster of data around a single age class is often related to herd management and/ or selective seasonal slaughter patterns (Reitz & Wing, 2001, p. 192). This pattern strongly suggests that, at BNW, pigs were produced and consumed with a preference for juvenile animals in the Iron Age.

Bovid remains were identified at all three sites. The bovid remains comprise a mixture of domestic and wild varieties. The ratio of identifiable elements of water buffalo to cattle at all three sites was in favour of water buffalo. This was mainly due to high amounts of water buffalo remains being found in Iron Age bone middens. It is only in the Iron Age at BNW that water buffalo out number cattle. The measurement data for water buffalo shows measurements close to the mean for the domestic water buffalo *Bubalus bubalis* (Appendix D, Appendix E, Appendix F, and Appendix G). Only three first phalanx elements identified of *Bubalus* sp. came from Neolithic contexts at BNW. Two of these from N100 general spit (8:5) and (8:6), were almost certainly from wild animals, based on their large size. Whereas, one distal end fragment from N100 general spit (8:1) was potentially a domestic specimen. The general spit (8:1) of N100 is a transition from the Neolithic to the early Bronze Age. However, as this first phalanx distal end fragment was not found in a dateable feature, its time period is debatable. In the Bronze Age contexts at BNW some elements were close to the mean measurements for the domestic water buffalo and some larger elements were probably from wild animals. Two elements were close to the mean measurements of domestic water buffalo; a distal metacarpal and a proximal left metatarsal were located in a bone midden in N96 feature 11 (4:3). The hard floor in the next spit, located 10cm below the bone midden feature, was dated to the late Bronze Age (Kanthilatha et al., 2014). Similar to the Bronze Age, in Iron Age contexts both domestic water buffalo and some larger elements, probably from wild animals, were observed in the measurement data. The domestic water buffalo were likely used as draft animals for ploughing fields. The presence of cut marks on water buffalo bones that are domestic in size, found at all three sites in this study, indicates domestic water buffalo were part of subsistence strategies. This likely relates to herd management, with the best draft animals kept for ploughing fields and old draft animals and unsuitable animals used as a food resource.

Bone elements close to the mean size for domestic cattle *Bos taurus*, were found at all three sites in this study. Domestic-sized cattle elements were also found in all time periods, from the Neolithic to the Modern and Historic periods at BNW. The previous excavations at BNW also found the remains of domestic-sized cattle bone elements in the Neolithic period (Kijngam, 2010). Findings from this thesis support the conclusion that the Neolithic people at BNW would have maintained a herd of domestic cattle.

The frequency of dog NISP were high at the site of BNW, however the NISP count was somewhat inflated by the three dog burials found at the site. Domesticated dog was identified from the teeth morphology and measurements at BNW (Appendix C). Not all *Canis* elements could be identified to a species level, as it is hard to separate domesticated dog *Canis familiaris* from wild golden jackal *Canis aureus*. The teeth elements that were identified were all from domestic dogs. No golden jackal was identified at any of the sites in this study. As no wild dog was identified at any of the sites it is most likely that the *Canis* elements belonged to domesticated dog *Canis familiaris*, rather than wild dogs *Canis aureus*. Dog remains had signs of butchery at both BNW and BSL. Butchered dog remains have also been found at the Neolithic site of An Son in Southern Vietnam (Piper et al., 2014). At the site of An Son there was no difference between the way dog remains and other animal refuse was deposited (Piper et al., 2014). This is not the case for sites at BNW, as articulated dog burials have been uncovered at the site in previous studies (Iseppy, 2012, p. 32). Likewise, two articulated dog burials were found during excavations as part of this study, with no signs of butchery. On the other hand, disarticulated dog remains with cut marks were deposited with other animal refuse in further features at BNW and BSL.

One of the dog burials at BNW contained grave goods, strongly suggesting that domestic dogs were valued beyond a food source. The burial of domestic animals with grave goods indicates the special role that animals would have played in the social life of the people who buried it (Morey, 2006). Domestic dogs in many past societies were utilised for hunting, security, pest control, and also as protection for herders of other domestic animals (Reitz & Wing, 2001, p. 294). It is not implausible that domestic dogs at BNW would have had a utilitarian role in the society. Nevertheless, it is also a likely that this role was more than just utilitarian, as a high level of care is seen in the dog burial. Further research on dog burials, including biometry and morphology of bone, DNA analysis, and grave good studies are needed to understand the human-animal relationship between domestic dogs and the people of BNW.

Cats were only identified at BNW. The higher NISP count in the Iron Age at BNW was due to the one Iron Age cat burial. The cat remains were all classified Felidae, two of the Felidae bone fragments were identified as Tiger at BNW. Due to their size the rest of the Felidae bones are most likely to have come from domesticated cats. However, they may be from smaller wild species such as leopard cat *Prionailurus bengalensis* or jungle cat *Felis chaus*. Similar to dogs, domesticated cats in many previous societies have had an active role in hunting, security, and pest control (Reitz & Wing, 2001, p. 294).

Only thirty-five bones were identified as chicken/ red junglefowl at all three sites. These bones could be from domestic chicken *Gallus gallus domesticus* or from the wild red junglefowl *Gallus gallus*, which is native to Southeast Asia. In the previous excavations of BNW, Kijngam (2010) also identified chicken/ red junglefowl in small amounts. Kijngam (2010) suggests it is possible the few bones of fowl from BNW are domestic, and that a flock of domestic chicken were kept at sites such as BNW. However, this is based on the small amount of fowl remains uncovered at these sites. If a flock of domestic chickens were maintained at a site like BNW one would expect a greater number of bones. Nevertheless, domestic chicken could have been traded or brought from another sites in the region to BNW, BSL, or NHR.

This section has examined the subsistence strategies relating to domestic animals at all three sites. The subsistence practices that involved domestic animals were similar at BSL and NHR. With bovid being the dominant domestic animal consumed at the sites. Second to bovid at BSL and NHR was pig. The age at death estimates for pig and the frequency of skeletal elements at BSL and NHR suggest that pigs might have been raised or butchered offsite. Whereas at BNW pig was more than likely produced and consumed onsite, as a greater amount of bone elements were found and a wider range of age classes were present. Only six fragments of bone belonging to *Canis* were identified at BSL and NHR. However, *Canis* was a greater part of subsistence strategies at BNW. Some domestic dogs at BNW would also have had special roles in the society worthy of a burial. The differences between the subsistence practices at the sites is further discussed in *6.4 Differences in Resources Site vs. Community* in this chapter.

6.1.2 Hunting

Deer was identified at all three sites in this study. The hunting of deer at all three sites targeted the Eld's deer *Rucervus eldii* and Schomburgk's deer *Rucervus schomburgki* species. The Eld's and Schomburgk's deer species were also identified by Kijngam (2010) as the most common species in the previous study at BNW. The higher amount of Eld's and Schomburgk's deer species might be due to the habitat in which these deer are commonly found. Both are found in lowland river floodplains and feed mainly on grasses (Francis, 2008). The Eld's deer is also known to sometimes enter rice fields to graze (Francis, 2008). The Sambar deer *Rusa unicolor* is most commonly found in secondary forests on sloping terrain. However the Hog deer *Axis porcinus,* like the Eld's and Schomburgk's deer, inhabits lowland floodplains and feeds mainly on grasses (Francis, 2008). The barking deer *Muntiacus muntjak* is found in a wide variety of forest habitats, from lowlands to hills (Francis 2008). The hunting of deer species, such as the Eld's deer, which are known to graze on rice crops, more than likely have the dual benefit of protecting crops and providing subsistence. The hunting of deer is no longer common practice in the Lao-Isan culture of northeast Thailand, as deer are rare in the area. It is likely that before the modern agricultural practices of cash crop cultivation began in the early 1950s, deer would have been hunted in rice fields in Lao-Isan villages, as they are today in the Hmong villages, with its remaining forest cover in the highlands (Johnson et al., 2003; Vityakon et al., 2004).

It was noted during the measurement of the pig teeth that some measurements at BNW were within the range of wild pig, *Sus scrofa scrofa*. However, due to the size overlap in wild and domestic pig teeth, there is a need for further analysis, perhaps using 3D geometric morphometrics, outlined by Owen et al. (2014). There were also larger-sized water buffalo and cattle elements from within the range of wild water buffalo and cattle at all three sites (BNW, BSL, and NHR). It is likely the wild animals would have been hunted to supplement the domestic animals in these sites.

Two bone elements were identified as goral *Naemorhedus* sp. at BSL. Due to the small size these could have been from the Chinese goral or the red goral. Both of these species are usually found in hilly terrain at elevations above 1000m in altitude, well above the elevations at BSL (Francis, 2008). These elements from the goral must have been brought to the site through trade or long distance hunting. This may show that the Iron Age communities in the Upper Mun River Valley had trade connections with upland communities. Other wild animals, such as the Asian elephant, tiger, rhino, and crocodile were identified in the assemblage at BNW. These animals were found in low amounts, and it is unlikely that these animals were a key target for hunters in prehistory at BNW.

This section has discussed hunting of larger mammals at BNW, BSL, and NHR. At all three sites the Eld's and Schomburgk's deer were found in greater amounts in comparison to other deer species, such as sambar deer. Other larger mammals, such as wild pig, cattle and buffalo, were also hunted. However, these animals seem to be targeted less than Eld's and Schomburgk's deer.

6.1.3 Fishing and Gathering Turtle and Tortoise

This study, and previous ones at BNW, has shown that fish is a major subsistence resource (Thosarat, 2010; Thosarat, 2012; Thosarat, 2012a). Fish remains at the sites of BSL and NHR were found in very low amounts in this study. The most commonly identified fish at BNW was the snakehead murrel *Channa striata* followed by the walking catfish genus *Clarias* sp., and the climbing perch *Anabas testudineus*. These freshwater fish species are likewise found in high quantities at other sites in Thailand, including Khok Phanom Di, Ban Na Di, and Ban Lum Khao (Higham & Kijngam, 1984; Kijngam, 1991; Thosarat, 2004). The Asian swamp eel *Monopterus albus*, the butter catfish *Ompok bimaculatus*, and the yellow catfish *Hemibagrus* sp. were also common at BNW. All of the taxon of fish with a high per cent of NISP at BNW are either very commonly found in floodplain rice fields, or utilise rice fields to spawn in the wet season (Lee, 1992; Rainboth, 1996). The fish that were found in greater numbers are the species that inhabit the rice fields, and stagnant ponds around rice fields, the entire year. These results strongly suggest that fish were caught in the fields and ponds around BNW and that there were extensive rice paddies and stagnant areas of water at the site.

The snakehead fish *Channa* genus highlights the use of fields and ponds, with the snakehead murrel *Channa striata*, which inhabits sluggish or standing water including rice fields and ponds, having the highest frequency of NISP at BNW (over 22 per cent of the total NISP) (Lee, 1992; Rainboth, 1996, p. 219-220). However, other species of the *Channa* genus, such as the forest snakehead *Channa lucius* and the giant snakehead *Channa micropeltes*, which inhabit moving streams and rivers, were found in low numbers at BNW (Rainboth, 1996, p. 219-220). The species that are commonly found in rivers and lakes and do not use rice fields to spawn, such as the carp or minnow from the Cyprinidae family, the Jungle perch *Hampala* sp., the wallago catfish *Wallago* sp., the forest snakehead *Channa lucius*, the giant snakehead *Channa micropeltes*, the Malayan leaf fish *Pristolepis fasciata*, and the gourami from the Osphronemidae family, were all identified in low amounts at BNW.

The range of methods used to catch these fish by modern communities in Cambodia is highlighted by Voeun (2006). These included hook-and-line, push nets, cast nets, gill nets, specialised traps, and seines. These river and lake species of fish are usually caught by line hook, nets, or damming the river (Rainboth, 1996; Voeun, 2006). The low numbers of river and lake species of fish at BNW suggests there was limited or no river fishing, with the majority of fish being caught in rice fields and ponds. There has been no fishhooks recovered from BNW, in contrast to the coastal sites such as Nong Nor and Khok Phanom Di, where fishhooks were recovered (Higham, 1993; O'Reilly, 1998a). A small quantity of bone bipoints has been uncovered at BNW, which could have been used as gorge hooks (Stenhouse, 2010). However, these types of points are found in low numbers and also might be related to craft practices such as textile production (P. Kerdsap, personal communication, December 2, 2014). A similar assemblage of fish remains to the ones found at BNW was identified at the Neolithic site of An Son in Vietnam. The most commonly identified fish at the site of An Son included snakehead, Asian swamp eel, and climbing perch (Piper et al., 2014). However, unlike BNW, fishhooks were also present in the artefact assemblage at An Son (Bellwood et al., 2011). This might explain the higher amounts of Asian swamp eel at An Son compared to BNW; Asian swamp eel can be dug out of rice fields during the dry season, as the species can survive out of water if kept moist, or caught by hook-and-line in the wet season (Thosarat, 2010, p. 169).

Turtle and tortoise remains were another aquatic resource that were common at BNW. The NISP for turtle and tortoise were undoubtedly inflated due to the nature of the carapace and plastron fracturing into small pieces, this is a part that can be easily identified from the animal. Most of the turtle and tortoise remains were from the Geoemydidae (box, pond, and water turtle), the Platysternidae (big-headed turtle), and Testudinidae (tortoise) families. Only a small number of elements were from the Trionychidae (soft-shelled turtle) family at BNW and BSL. Piper et al. (2014) show the same trend from the site of An Son in Vietnam. They suggest the abundance of soft-shelled turtle shows a deliberate targeting of a specific genus or species of turtle. Furthermore, it is suggested that the method used to gather the turtle was digging them out from their burrows on the sides of river banks or by trapping. Turtles are also often caught in traditional traps that target other fish species. These techniques were likely practiced in the Upper Mun River Valley in prehistory.

This section has examined aquatic resources at all three sites. The high amount of fish remains found at BNW is more than likely from fishing stagnant ponds and rice fields, as the species profile is strongly suggestive of these environments. The degree to which these ponds and rice fields were actively managed is discussed further in *6.2 The Management of Freshwater Resources* in this chapter. Other aquatic resources, such as turtle, which were found at all three sites were likely gathered or caught in traps. The use of bamboo traps to catch fish is discussed in *6.3 The Use of Traps* in this chapter.

6.2 THE MANAGEMENT OF FRESHWATER RESOURCES

Aquaculture plays an important role in food security and the economy of Southeast Asia in contemporary society. The modern use of rice fields as a source of freshwater fish, shellfish, turtle, frog, freshwater prawn, crab and even insects, has been given the title rice-fish farming (Little et al., 1996). The relationship between rice, fish, and farming in Thailand was established as early as the thirteenth century AD, during the Sukhothai period. In a well-known stone inscription from the Sukhothai period, King Ramkhamhaeng proclaimed, "*In the time of King Rãma Gamhèn this land of Sukhodai is thriving. There is fish in the water and rice in the fields*" (Griswold & Prasert, 1971, p. 205). Today rice-fish farming is practiced in Thailand, Vietnam, Indonesia, and to a lesser extent in the Philippines (Piumsombum, 2001).

One of the approaches used in modern rice-fish farming in northeast Thailand is creating fish trap ponds in rice fields (Lee, 1992). The ponds are dug into the edge of rice fields, at a deeper level than the surrounding rice field (Lee, 1992). Fish would become trapped in the ponds as floodwaters subsided in the dry season. There are a variety of freshwater fish are caught in fish trap ponds. Although, the most dominant species caught in northeast Thailand today are the walking catfish *Clarias batrachus*, snakehead murrel *Channa striata*, and climbing perch *Anabas testudineus* (Lee, 1992). Rice-fish farming, and the use of fish trap ponds common in northeast Thailand today, may have also been prevalent in prehistoric societies. The three species caught in modern rice field fish trap ponds identified by Lee (1992) are by far the highest species of fish identified at BNW in this study. However, due to the reuse of ancient rice fields over millennia, we may never know if fish trap ponds were used in prehistory in northeast Thailand or if other trapping methods were used in fields. Also, current research suggests that wet rice fields only became well established in the first millennium AD, therefore, would not have been practised in the Bronze Age or Neolithic (N. Chang, personal communication, January 6, 2013). The use of traps to catch fish is further discussed under the heading *6.3 The use of traps* in this chapter.

O'Reilly (2008) introduces the idea that the Iron Age moats surrounding prehistoric sites in northeast Thailand might have been used for the aquaculture of plants or animals. Higham (2011) also notes that the moats surrounding Iron Age sites like Noen U-loke, Non Muang Kao, and BNW in the Upper Mun River Valley, would have contained fish. It is further stated the moats would not only have provided water during the dry season, they would have also ensured a constant supply of aquatic food, or perhaps resources for feasting ceremonies. The most common fish species used in aquaculture systems in Thailand today is the *Tilapia* genus, which was introduced to Thailand in 1965 (Piumsombum, 2001). However, the walking catfish *Clarias* sp. and silver barb *Barbonymus gonionotus*, which are native to Thailand, are also popular in modern aquaculture systems (Piumsombum, 2001). One of these fish, the walking catfish, is common in the BNW assemblage in this study.

There was also an increase in the ratio of NISP by volume (m^3) through time of walking catfish, in comparison to other species of fish, at BNW in the same time period. The walking catfish was the third most common species behind the snakehead murrel and climbing perch in the Neolithic (Figure 59). The walking catfish increased to similar proportions as the climbing perch and walking catfish in the Bronze Age (Figure 57). The walking catfish then become the second most common species in the Iron Age, and, finally, the most common in the Historic period (Figure 55 and Figure 53). This trend was also noted in previous excavations at BNW, with walking catfish changing from the fourth most identified species in the Neolithic to the most commonly identified species in the Iron Age (Thosarat, 2010, p. 170; Thosarat, 2012a, p. 52). The increase in walking catfish over time may demonstrate a shift from rice-fish farming to a pond or moat system of aquaculture. The Iron Age moats at BNW would have been the ideal habitat of the *Clarias* genus to survive the dry season, as it known to live in very low muddy ponds with little oxygen or food in the drier months (Rainboth, 1996, p. 162-163).

The use of moats for aquatic resources may explain the lack of fish in the Iron Age site of BSL and NHR in this study, as both of these sites do not have Iron Age moats. Also, the analysis of shellfish remains within individual excavation units, although not completed as part of this study, was recorded in low amounts at BSL and NHR in comparison to BNW. It is clear from the abundance of the species of fish identified at BNW, both in this study and previous research in the region, it is more than possible that fields and Iron Age moats were being utilised for their aquatic resources. However, the level to which the resources were managed at these sites in prehistory is unclear at this stage.

6.3 THE USE OF TRAPS

The use of traps for fishing and hunting animals was introduced in *Chapter 2: Background*, *2.3 Contemporary Subsistence Strategies within Southeast Asia*. The extensive use of traps by the Hmong and Lao-Isan cultures has shown their importance as a hunting technique today, and should not be overlooked in an archaeological context. Fish constituted over half of the NISP recovered from BNW in this study. High quantities of fish have also been identified at a number of prehistoric sites across Southeast Asia (Piper et al., 2014; Toizumi et al., 2011; Voeun, 2006). There is no doubt that fish played a major part in the subsistence diet of prehistoric communities in the Upper Mun River Valley. In contemporary culture an array of bamboo traps are used for fishing in northeast Thailand. Figure 99, shows some of these traps from the modern village of BNW. Similar bamboo fish traps are found throughout Southeast Asia today. Few signs of these contemporary cultural practices would show up in the archaeological record, due to their bamboo construction and the poor preservation of wood in the archaeological context. It is, however, feasible that comparable traps were utilised to catch fish in northeast Thailand in prehistory at sites such as BNW. However, regional comparative cultural studies of fish traps and the techniques used are needed in order provide more robust analogies.

Traps are also used today within the Hmong and Lao-Isan Cultures to catch terrestrial animals such as lizards, birds, small mammals, and large mammals. Traps are used in rice fields to catch animals for consumption, and also have the additional advantage of aiding pest control. This practice is still common in present day rice farming communities in Southeast Asia, where traps are placed along fence lines or near rice fields in order to catch pest animals (Tayanin & Lindell, 1991). The trapping of large mammals, such as deer, is no longer common practice in the Lao-Isan culture of northeast Thailand, as deer are rare in the area. However, the trapping of agricultural pests, such as rats in rice fields with bamboo snare traps, is a common practice (Somnasang et al., 1998).

It is more likely that traps using perishable materials, such as wood and bamboo, would have been a part of the subsistence strategies of prehistoric communities in the Upper Mun River Valley. Other zooarchaeological studies in the region have also made these conclusions (see. Voeun, 2006). However, caution is required when drawing these conclusions from a contemporary culture context to a prehistory context. Modern or historical Isaan practices, for example, would have originated when Lao-Isan people migrated to the region at the beginning of the first millennium AD (Myers, 2005). These practices provide a comparable analogy to examine subsistence strategies in the region, although may not directly reflect typology, use, and cultural significance.

Figure 99: Three types of bamboo fish trap from the modern village at BNW. From the top; camouflage trap, bottom left horizontal trap for snakehead, bottom right plunging trap

6.4 DIFFERENCES IN RESOURCES SITE VS. COMMUNITY

Past research in the Upper Mun River Valley has focused on resources at a site by site basis (Higham, 2004a; Higham et al., 2007; Higham, 2012; Higham, 2012b; Iseppy, 2012; Kijngam, 2010; McCaw, 2007; Thosarat, 2010; Thosarat, 2012; Thosarat, 2012a). The sites are then compared to one another, and conclusions are made based on differences in resources acquired. The main findings using this method can be seen in Table 11 for the three Iron Age sites in this thesis. More recent work has demonstrated that community was the major social unit in prehistory in the Upper Mun River Valley (Evans, 2016). The social structure only shifted to sites as the major social unit in protohistory, where evidence of hierarchy in site size is found and distribution develops (Evans, 2016; Evans et al., 2016). It has been shown that in prehistory small linear communities clustered along the edges of water ways and tributaries, sharing resources in the Upper Mun River Valley (Evans, 2016). Based on this new evidence, Figure 100 shows the main animal resources in the Iron Age that were used in a bordered community, and the presence of what might be a linear community in the blue and red. The red area shows a possible community that is utilising freshwater fish as their main resource, which is supplemented by a mixture of wild and domestic animals. The blue area demonstrates a potential community utilising domestic bovid and pig as their major resources, which is supplemented by a small amount of wild animals such as deer. The green dashed circles designate closely interlinked communities that would have exchanged resources. The excavation of new sites in close proximity to one another, and in-depth analysis of their zooarchaeological record, will assist in understanding how resources were used in bordering communities.

Table 11: Conclusions based on differences in resources at the three sites

Ban Non Wat	**Ban Salao**	**Nong Hua Raet**
Fishing is a major part of the subsistence strategy	Fishing is not a major part of the subsistence strategy	
Lower amount of bovid	Higher amount of bovid, perhaps related to site use	
Higher amount of pig remains related to ceremony	Lower amount of pig remains	
Pigs raised on site	Pigs probably raised off site	
Rats and mice present = rice or millet agriculture and storage	Low or no rats or mice = no agriculture or storage of rice or millet	
Hunting and trapping of wild animals to supplement domestic animals		

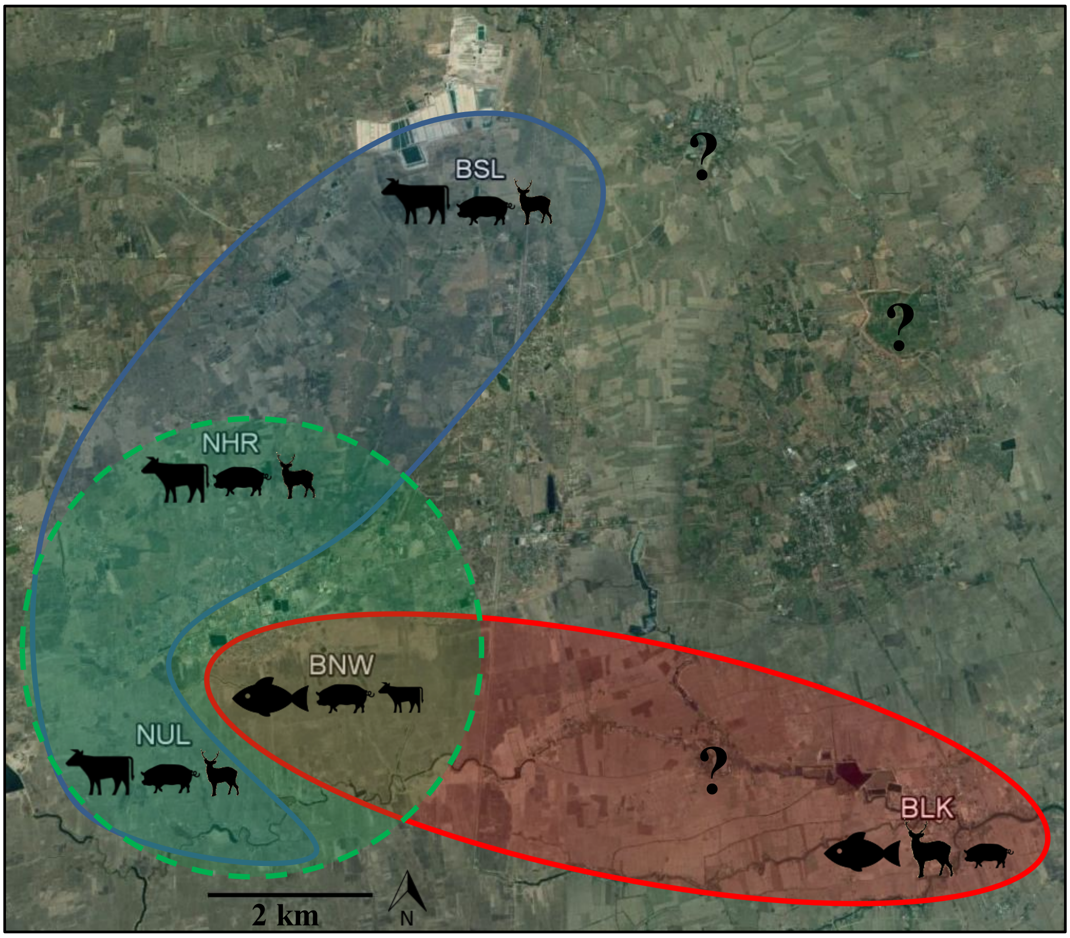


Figure 100: The Upper Mun River Valley showing the archaeological sites of Ban Non Wat (BNW), Ban Salao (BSL), Nong Hua Raet (NHR), Noen U-Loke (NUL), and Ban Lum Khao (BLK) and the most common resources used by each site. Other archaeological sites in the area (?). The red area shows a possible community that is utilising freshwater fish, the blue area shows a possible community that is utilising domestic bovid and pig, and the dashed green circle shows an interlinked community that would have exchanged resources.

6.5 RITUAL FEASTING

The high amount of pig remains at BNW shows the importance of this resource to the community, with pig constituting 11.54 per cent of all NISP considered for this thesis (Figure 39). This is the most prevalent mammal found at BNW. Higham (2010a) states that pig at BNW was a part of feasting during mortuary rituals or placed in the grave as offerings to the dead. Higham (2012b) elaborates on this stating that 39 per cent of burials at BNW contained pig remains, in comparison to the site of Ban Lum Khao, with only six per cent. The site of Noen U-Loke to the west of BNW, shows pig being preferred as burial offerings (McCaw, 2007). Although, the number of pig remains is high in burial contexts at BNW, the pig NISP within burials are considerably lower than those recovered from features and general spits (Figure 48). Pigs within burials make up less than five per cent of the overall NISP, when comparing burial contexts with features and the general spits. The low NISP values in burial contexts is mostly due to a larger volume of sediment being removed from the general spit and feature contexts in comparison to burial contexts. However, these results show that pig is found in large numbers across the site, and it is not particularly abundant within burials when all contexts are considered. A similar trend can be seen with other large mammals, including cattle and deer. This indicates that pig would have been a key part of everyday food subsistence, not only incorporated into burial rituals or raised specifically for ritual feasting. Death is often unplanned and pig is a well-established food source, which is easily incorporated into mortuary ritual. Other animals, such as deer with would have taken more time to hunt.

Fish are another animal that has been identified by researchers in Southeast Asia, as commonly associated with burial contexts (O'Reilly et al., 2015). The results for this thesis show that fish remains at BNW accounted for 59 per cent of all NISP (Figure 39). A small amount of NISP of fish taxa were recovered from burial contexts in comparison to general spits, features, and grave fill context (Figure 49). The high NISP values in fish taxa in the general spits, features, and grave fill context is due to wet sieve sampling of these contexts. Residue analysis of ceramics from burial contexts at BNW has established the presence of fatty acid, most likely from plant, mammal, fish, or a combination of these (Hauman, 2013). The fermentation of fish with salt is commonly practiced in northeast Thailand today. Fish and crabs are collected from rice fields and fermented during the wet season for consumption in the dry season. Yankowski et al.'s (2015) study on salt and the fermentation of fish in modern villages in the Upper Mun River Valley identified several species of fish commonly used for fermentation; namely the *Anabas testudineus*, *Henicorhynchus siamensis*, *Clarias batrachus*, *Pristolepis fasciatus*, *Notopterus notopterus*, and *Channa striata* species. Most of these species were identified in this thesis and some in high amounts such as *Channa striata*, *Anabas testudineus* and *Clarias* sp., which would include *Clarias batrachus*. The high amounts of fish species used for fish fermentation found in all contexts, would suggest that fermented fish was part of everyday subsistence. Like pig, fermented fish would have been a well-established food source easily incorporated into mortuary rituals.

Bovidae remains are found in high amounts in Iron Age bone midden features at BNW and BSL (Figure 63 and Figure 85). These features have been previously interpreted as butchery floors, as a product of increased ritual mortuary feasting in the Iron Age at BNW (Higham, 2012; Iseppy, 2012). This was due to their close stratigraphical connections with Iron Age burials. However, the results from this thesis show that bone midden features were found at BSL; a site in which, to date only one infant burial has been found. This thesis also found bone midden features in areas of BNW, such as K500, that similarly only had one burial. These features at BSL and K500 on the northeast side of BNW were not associated with burials. These features could be examples of simple waste disposal linked with everyday butchering and cooking processes.

Another hypothesis for these features is seasonal opportunistic hunting of wild animals. It has been shown by Lekagul (1954) that wild animals, including deer, were traditionally hunted in Thailand utilising the floodwaters during the wet season (Figure 101). The majority of *Bubalus* and *Bos* remains from the features measured in this study were larger than their domestic comparative samples, and are most likely from wild species. It is also worth noting that most of the Bovidae elements that were not measured were larger than their domestic comparative sample. A third hypothesis is that the bone midden features are seasonal feasting events linked to rice harvesting processes. These activities would have involved large amounts of people, and might have involved the wider community. However, estimating the age and season of death, feasibly using tooth eruption and wear, crown height, and dental cementum analysis of teeth from the Iron Age bone midden features, is needed in order to test seasonal feasting hypotheses.

Figure 101: A Traditional Thai deer hunting method, utilising the flood waters in the wet season (Lekagul, 1954)

6.6 CHANGES TO THE SUBSISTENCE STRATEGIES OVER TIME

The previous section of this chapter has looked at subsistence strategies, the management of aquatic resources, the use of traps, ritual and seasonal feasting, and the differences between the sites. This section discusses changes over time, specifically the subsistence strategies employed at the site of BNW, from the Neolithic to the Iron Age period. It was observed from the results, that there was a change over time in the subsistence strategies at the site of BNW. The subsistence strategy changed from a focus on wild aquatic and terrestrial resources, to one more reliant on domestic animals as well as wild aquatic resources. The Iron Age context at BSL and NHR also showed more reliance on domestic animals than other resources.

The Neolithic inhabitants at BNW were highly reliant on wild aquatic resources including fish, turtle, and tortoise. Shellfish were also one of the aquatic resources utilised heavily by the Neolithic inhabitants of BNW. Although the analysis of shellfish remains at BNW were not investigated during this study, it was noted that excavations of large shell midden features, with high quantities of shellfish, were uncovered in Neolithic contexts during the excavation (Figure 102) (N. Chang, personal communication, January 6, 2013). The previous excavation at BNW also contained a large shell midden in the Neolithic layers identified by Thosarat (2010). Thosarat (2010) states that shellfish were a significant part of the Neolithic diet at BNW. The results of this thesis also demonstrate that turtle and tortoise were a significant aquatic resource in the Neolithic. Large amounts of turtle and tortoise remains were also recorded in Neolithic shell midden features at BNW during this study. It is highly likely shellfish, turtle, and tortoise during the Neolithic were gathered at the same time, given that they inhabited the same environment and there were remains found alongside each other in Neolithic shell middens. Additionally, there is a decline in the amount of turtle and tortoise remains from the Neolithic to the Bronze Age, which also demonstrates a drop in the numbers of shellfish. Conrad (2015) mentions that there might be a relationship between the consumption of turtle and tortoise, and shellfish, and the transition to agriculture and domestic animals in the late Holocene.

Figure 102: Neolithic shell midden features at BNW (image by Chang 2008)

The relationship between the use of reliable aquatic food resources and the transition to sedentary lifestyles can be seen throughout the world at different time periods. One example is the prehistoric Jomon culture (c. 10,000 BC to c.400 BC) of Japan, which was predominantly a hunter gather and fishing society (Habu, 2004, p. 3, and 39), although, unlike most hunter gather societies, the Jomon had a sedentary lifestyle. The hypothesis on how the Jomon culture maintained such a complex hunter gather society is grounded in the studies of their subsistence strategies. Yamanouchi (1964) hypothesised that salmon fishing, along with deciduous acorn collection in the eastern parts of Japan, was able to support a large sedentary population. This idea was based on comparative cultural studies from the Ainu in Hokkaido and Indigenous peoples of California. The Yamanouchi (1964) hypothesis still remains a topic of debate, as the number of salmon remains from Jomon sites is fairly low (Matsui, 1996). Another example of the link between reliable aquatic resources and sedentary lifestyles is the elaborate eel trap system near Toolondo in western Victoria, Australia. The eel traps were constructed by the Gunditjmara Indigenous Australians, with initial dates suggesting the trap complex was constructed within the past 500 years (McNiven & Bell, 2010). The eel traps were a series of artificial channels, dug to join two swamps 2.5km apart (Flood, 2004, p.

242). Early ethnographic evidence in the region, describes types of dwellings forming ‘villages’ (Flood, 2004, p. 242). The access to a rich seasonal eel supply allowed this predominantly hunter gather society to settle in the area on a semi-permanent basis.

The use of reliable aquatic resources in the Jomon culture of Japan and the Gunditjmara culture of Australia, is comparable to the relationship between freshwater resources and the settlement of the Upper Mun River Valley of northeast Thailand. The results of this thesis show that the Neolithic contexts at BNW were rich in turtle and tortoise, fish, and shellfish. The first people to settle in the Upper Mun River Valley were located near to or on the floodplain, with access to water and an abundance of aquatic resources. To date in the Upper Mun River Valley, Neolithic sites have predominantly been found in the lowland floodplain terrace zone in an elevation range of 151 to 156 metres above sea level (Evans, 2016, p. 178). This relationship was more than likely driven by access to water for agriculture. However, the ongoing success of these settlements would have depended upon access to reliable resources, such as the aquatic resources that can be gathered in years of low agricultural yield.

Over time, from the Neolithic to the Iron Age, people moved away from aquatic resources such as turtle and tortoise, and shellfish. These slow moving aquatic resources can be easily over exploited and are slow growing, taking a while for populations to recover (Stiner & Munro, 2002). It is probable that Neolithic people at BNW over exploited slow moving aquatic resources reducing their population size. Boyd & Chang (2010) have also shown that the environment is gradually drying, and there is a reduction in swamps and flooded areas in the Bronze Age period in the Upper Mun River Valley, which would also cause a reduction in the population sizes of aquatic resources.

Freshwater fish remained a substantial part of the subsistence strategies throughout all time periods at BNW. Yuan et al., (2008) study on the exploitation of animal resources in the Chinese Neolithic, showed regional differences in subsistence strategies. The Neolithic people in the Yellow River region turned from hunting wild animals to the rearing of pigs, dogs, sheep and cattle, and the peoples of the Yangzi Valley also reared animals however, continued hunting and fishing of wild animals into their Bronze Age. Yuan et al., (2008) suggests that this maybe the effects of different macro-environments on the development of human subsistence strategies. The two regions have different ecological systems, with the Yellow River Valley characterised by drier seasonal conditions and Yangzi Valley by wetter monsoonal conditions.

At BNW there was a shift away from terrestrial wild resources, from the Neolithic to the Iron Age. Deer NISP, for example, was a wild resource found in greater amounts in Neolithic contexts by volume (m^3) at BNW than terrestrial domestic resources, such as pig and cattle (Figure 60). In the Bronze Age deer decreased and pig were found in greater quantities, and in the Iron Age deer decreased again, with pig and cattle found in greater amounts. It was suggested by McCaw (2007, p. 513) that a decrease in deer at the Iron Age site of Noen U-Loke to less than five per cent of the total MNI in the upper layers, was due to intense hunting, which depleted the resource. The data from this thesis shows an increase in reliance on domestic animals, while the reliance on wild animals stayed relatively low. The reason the society at BNW increased their reliance on domestic animals over time might be addressed by looking at the subsistence lifestyles of different contemporary agrarian societies. For example, the contemporary Hmong and Lao-Isan subsistence strategies are interconnected with the agricultural system they employ. The low intensity swidden agriculture used by the Hmong allows hunting practices to be carried out all year round (Johnson et al., 2003). In comparison, the high intensity paddy farming of the Lao-Isan cultures limits available time for hunting to a third of the year (Kunarattanapruk et al., 1998). Although other cultural and environmental factors may play a part, such as the decline in the number and diversity of plants and animals during drier months, there remains a strong relationship between the intensity of the agricultural practices and the hunting, gathering, and trapping of wild animals. This can explain the trend from wild to domestic resources seen at BNW; the lower intensity agriculture of the Neolithic would have meant there was less time spent on rice farming, and allowed more time for hunting deer and other game.

The shift in agricultural practices is likely due to the exploitation of a more seasonal environment in the Iron Age, and the increase from low-density subsistence settlement in the Bronze Age to high-density settlement in the Iron Age and post-Iron Age periods (Boyd & McGrath, 2001). The seasonality of high intensity rice farming would mean that there was more time during the drier months for other activities (Johnson et al., 2003; Kunarattanapruk et al., 1998). The down-season of agriculture, coupled with the higher population in the Iron Age, would have been a factor as to why other mounds sites, such as BSL and NHR, were inhabited or used for other resources.

Additionally, this may explain why these Iron Age sites are not moated and had low amounts of pottery, bones, shell, artefacts, and burials in comparison to BNW. Potentially, the sites BSL and NHR are seasonally occupied mounds that are used during the day for salt making, hunting, gathering, and clay sourcing, with inhabitants returning home to sites such as BNW for the evening. The sites of BSL and NHR have both been identified as possible prehistoric salt making locations (Yankowski & Kerdsap, 2013). This hypothesis is also supported by the subsistence strategies identified at these sites. Very low numbers of fish bones were found at both BSL and NHR, this lack of such a reliable resource suggests that the occupation level at these mounds is relatively low. Furthermore, the notable lack of fish that are commonly caught in rice fields would suggest that wet rice agriculture was not practiced at these sites. This also explains the lack of mouse and rat remains found at these sites, especially those species associated with urban areas agricultural areas (Francis, 2008).

6.7 SOCIAL CHANGE AND THE ZOOARCHAEOLOGICAL RECORD

It has been demonstrated in this thesis that subsistence strategies shift from the Neolithic to Iron Age at BNW; from a strategy focused on hunting, trapping, and collecting of wild animals supplemented with domestic animals in the Neolithic, to a mixture of wild and domestic animals coupled with fishing in the Bronze Age, to a strategy focused more on domestic animals and fishing in the Iron Age. However, close by sites of BSL and NHR had lower amounts of wild animal resources, including fish. Similarly, the Iron Age site of Noen U-Loke, west of BNW, showed low numbers of wild animal resources and higher quantities of cattle remains (McCaw, 2007, p. 513). The section below discusses how one of the objectives of this thesis, to examine subsistence strategies in early communities in the Upper Mun River Valley of northeast Thailand, and reveal if these strategies changed throughout time, relates to broader theories and models of social, environmental, and technological change. More specifically how these theories and models relate to subsistence shifts within a closely located group of sites like BNW, BSL, and NHR.

The results are inconclusive as to which model of social change in Southeast Asia the data from this thesis supports. On the one hand, such findings align with hierarchical models of social change in Southeast Asia, as there is an increase in animal husbandry practices as society moves towards a more state-like structure (Higham, 1989, pp. 153-155). Further evidence to support a hierarchical model is found in the rise in evidence of ritual feasting, as reflected in the bone midden feature from BNW and BSL. The results do show an increase in domestic animals over time as the society moves from a village based society towards a town base in the Iron Age. However, the fishing, hunting and trapping of wild animals is not completely abandoned, still forming a key part of the subsistence strategy, well into the Iron Age.

The results of this thesis also suggest that some elements of the heterarchical model best fits the data, with different assemblages identified at different sites in the same region. This may be a sign of specialisation in craft production or other activities such as salt making, hunting, gathering, and clay sourcing. However, these activities might be seasonally practiced at sites such as NHR and BSL, and therefore do not represent activities and assemblages at a site level. It is also worth noting that the heterarchical model can include some hierarchical trajectories that reorganise over time. Therefore the heterarchical model could still explain the changes in subsistence strategies at BNW (Crumley, 1995; White, 1995).

There is evidence in this thesis that supports the integrated social and environmental mutual change model. Most notably the shift to intensive agriculture and an increasing reliance on domestic resources in the Iron Age, arguably driven by or related to the environment becoming more seasonal in this time period (Boyd & Chang, 2010). Also, the model states that the Bronze Age and early Iron Age was a period of stability allowing long-term varied social adaptation in optimal environmental conditions. Such a situation allows for gradual change, both of social and natural conditions, without major or significant disruptions. It could be argued from data in this thesis that there was a gradual shift or decline in the use of wild animals in the Bronze Age and Iron Age (Figure 60). However, the spike in pig and fish in the Bronze Age context at BNW suggests that this was not a gradual shift (Figure 60 and Figure 61).

The ritual feasting model has been proposed as a major factor in the intensification of production, leading to the domestication of plants and animals in Southeast Asia (Hayden, 2009). Although, this model focuses on the social changes from pre-agricultural hunter-gatherer societies to farming societies, the ritual feasting model can also be applied to an intensification of agricultural practises. Current research suggests that wet rice fields only became well established in the first millennium AD, and would not have been practised in the Bronze Age or Neolithic (Castillo, 2011). The evidence to support the ritual feasting model is the increase in Iron Age feasting activity (possibly related to seasonally harvesting), found in bone midden feature from BNW and BSL. Furthermore, a change from staple foods, such as shellfish, turtle, and tortoise to luxury foods items such as domesticated animals. However, hierarchical and heterarchical models incorporate ritual feasting and luxury items as evidence of social change. Hayden (2004), also states that technological innovations, including fishing technologies (nets, weirs, fishhooks, leisters), mass food gathering techniques, processing technologies, and long-term storage technologies, made it possible to produce surpluses on a dependable basis in favourable environments. However, evidence of subsistence change in favourable environmental conditions is also consistent with the integrated social and environmental mutual change model.

There appears to be zooarchaeological evidence to support elements of several models of social change. This may relate an overlap within the structure of the models themselves, or that the zooarchaeological dataset cannot fully represent the individual models because these models use multiple lines of evidence, such as burial goods, settlement size, pottery typology, and landscape and environmental patterns.

6.8 SUMMARY AND FUTURE DIRECTIONS

This chapter discussed the major findings from the identification and analysis of vertebrate faunal remains from the prehistoric archaeological sites of BNW, BSL, and NHR in the Upper Mun River Valley. Initially, this chapter compared the subsistence strategies of the sites of BNW, BSL, and NHR in the Iron Age. At the site of BNW a broad spectrum of strategies were employed, including the raising of domestic pigs and cattle, hunting for deer, gathering turtle and tortoise, and fishing in rice fields and ponds, most likely with wooden traps. At BSL and NHR the strategies were much narrower, and focused on domestic animals such as cattle and pig. One interpretation is that these differences were due to site use, and related to seasonal occupation of sites such as BSL and NHR. It was shown that if these differences are analysed as a community unit, groups of linear communities specialising in one or two resources can been seen.

The evidence for ritual and seasonal feasting was also examined in this chapter. It was suggested the well-established food sources, such as pig and fish, were incorporated into mortuary rituals at BNW. Additionally, the Iron Age bone midden features at BNW and BSL were examined. The results from this thesis show that bone midden features, which contain a high amounts bovid remains, are not related to mortuary ritual. An alternative explanation for these features is seasonal opportunistic hunting of wild animals or seasonal feasting events linked to rice harvesting processes.

Lastly, the changes to subsistence strategies over time and the corresponding social changes were discussed in this chapter. It was observed that the communities in the Upper Mun River Valley become more reliant on domestic animals as part of their subsistence strategies over time. This shift is likely due to an intensification in rice farming processes, and an increase from low-density subsistence settlement in the Bronze Age to high-density settlement in the Iron Age, increasing the need for a reliable domestic animal food source. Although a shift from wild to domestic animals was identified, it is inconclusive as to which current model of social change in Southeast Asia the data supports, with evidence to support elements of each model. This could relate to overlap within the models themselves, or that no current model focuses on agriculture as a driver of social change.

6.8.1 Future Directions

This thesis has identified and analysed vertebrate animal remains from three newly excavated sites in the Upper Mun River Valley. However, this is just the starting point for a range of questions that could be investigated in future studies. Due to the substantial volume of animal remains uncovered at BNW, the research directions are numerous. This section will go through some of the future research directions in areas such as identification and classification of faunal remains, subsistence strategies, and further investigation of features found at BNW, BSL, and NHR. This research has highlighted the need for more robust and consistent sampling methods to be employed at larger scale excavation projects in northeast Thailand. In the future sampling methods and sizes should be kept consistent in order to facilitate better comparisons between assemblages. Additionally, similar excavation square sizes and dimensions, number of excavation squares within sites, and location within the overall site, would aid future comparisons between sites.

The remains of turtle and tortoise from all three sites would benefit from further identification to a genus or species level. This would help in narrowing down which species were targeted and which environments were being exploited, especially in the early Neolithic phase of the sites, when turtle and tortoise remains are numerous. This could be undertaken through the use of comparative carapace and plastron examples and literature, such as Nutaphand (1979) and Stuart and Platt (2004).

Projectiles such as pellet bows and also an array of traps are used for contemporary hunting and fishing in northeast Thailand. Few signs of these contemporary cultural practices show up in the archaeology, due to the poor preservation of wood. Pellet bow pellets are the one exception to this, and are found throughout the archaeological context at many sites in Southeast Asia. Pellet bow pellets provide a unique chance to study hunting practices and compare them to faunal assemblages. At BNW there are two peaks in the frequency of pellet bow pellets, one peak is during the Neolithic and the second during the later Bronze Age (Higham, 2010, p. 127). It would be valuable to compare to the volume of small mammals and bird bones from wet sieve samples over time at BNW, to see if there is a correlation to the peaks of pellet bow pellets in the Neolithic and later Bronze Age.

A future study looking at seasonality of subsistence strategies and changes over time would help to confirm or refute the hypothesis that Iron Age communities in the Upper Mun River Valley have less time for hunting and gathering due to intensification of wet rice farming. A working hypothesis to develop such a study on the seasonality of wild of resources over time is:

Iron Age communities in the Upper Mun River Valley were hunting large wild animals seasonally, as part of their subsistence strategies

To test the seasonal feasting hypothesis estimating age of death and season of death, feasibly using tooth eruption and wear, crown height, and dental cementum analysis of teeth from the Iron Age bone midden features from BNW and BSL uncovered during the *Society & Environment before Angkor: Ban Non Wat & the Upper Mun River Catchment in Prehistory* Project, could be completed. The tooth eruption, wear rate, and crown height of the mandibular of cattle, water buffalo, and deer following the methods outlined in Grant (1982), would provide general season of death estimates. The deer require further classification completed in order to separate the deer mandibles at a species level, as each species of deer has its own eruption and tooth wear patterns (Chapman et al., 2005). Dental cementum analysis, is one technique used to study season of death (Jones, 2012; Pike-Tay et al., 1999; Pike-Tay et al., 2008). Dental cementum utilises thin sections of teeth to microscopically analyse annual growth rings. These layers of cementum vary in thickness and in the angle that the collagen fibre mineralises, which is due to the seasonal changes in food toughness (Stutz, 2002). Every different layer represents a season, and the outermost layers denote the season-of-death (Jones, 2012).

Chapter 7: Conclusions

This thesis aimed to address the hypothesis that:

Prehistoric communities in the Upper Mun River Valley became more reliant on domestic animals as part of their subsistence strategies over time, from the Neolithic to the Iron Age

After examining the zooarchaeological remains from three sites, BNW, BSL, and NHR, the results from BNW strongly suggest the communities in the Upper Mun River Valley become more reliant on domestic animals as part of their subsistence strategies over time. The cause of the shift is likely two fold: firstly the intensification of wet rice farming would have left less time for hunting and gathering, and secondly, socio-cultural change in subsistence strategies led towards a more reliable domestic animal food source. The domestic animals were later incorporated into rituals, such as mortuary feasting or seasonal feasting events, possibly linked to seasonal rice farming.

Additionally, this thesis aimed to study a further series of objectives. Firstly to identify and analyse vertebrate animal remains from prehistoric sites in the Upper Mun River Valley of northeast Thailand.

This objective was achieved through the identification of 22283 bone pieces into 57 taxon groups from the three sites of BNW, BSL, and NHR. The animals identified were a range of wild and domestic examples from terrestrial and aquatic ecosystems. The major animals represented included a large proportion of pig, bovid and deer, as well as freshwater fish and turtles. After the initial identification process further analyses were completed on the contexts in which the bones were found, including the proportion of grouped elements present in bovid, pig, and deer, and further age at death estimates for pig. The results are presented in *Chapter 5: Results* as a series of tables, and summarised in in *Chapter 5: Results 5.5 Summary*.

A second objective was to integrate a comparative cultural study into the zooarchaeological analysis of animal remains, within these prehistoric communities and the broader Southeast Asia region.

The integration of a comparative cultural study was accomplished through a review of the existing literature in *Chapter 2: Background*, *2.2 Contemporary Subsistence Strategies within Southeast Asia*. The comparative cultural study revealed that the relatively low intensity swidden agriculture used by the Hmong allows for hunting practices to be carried out all year round. In comparison, the high intensity paddy farming of the Lao-Isan cultures limits available time for hunting to a third of the year. Additionally, the use of traps to catch animals was a technique used by both groups, which was a critical component of subsistence strategies in Southeast Asia. These perspectives, and others generated by anthropological accounts of modern ethnic groups, were used to interpret the zooarchaeological record from the three prehistoric sites in Upper Mun River Valley. Integrating a comparative cultural study has led to the conclusion that the seasonal nature of intensive Iron Age agricultural practices may have had an influence on when wild animals were hunted and to what extent. However the type of animals hunted appears to stay consistent over time.

The third and final objective was to examine subsistence strategies in early communities in the Upper Mun River Valley of northeast Thailand, and reveal if these strategies changed throughout time, and if and how these changes are related to social, environmental, and/or technological change.

The results of this thesis revealed that the subsistence strategies changed both throughout time, from the Neolithic to the Iron Age, and across different site types. For example, the early Neolithic communities of the Upper Mun River Valley relied heavily on aquatic resources such as turtle, fish, and shellfish. Wild animals such as deer were also hunted in greater numbers in the Neolithic in comparison to domestic animals such as pig and cattle. Over time evidence of domestic animal use increased within the sites examined, as communities moved towards a more seasonally based agricultural lifestyle. In the Bronze Age pig remains were more frequently recovered than deer and turtle remains. By the Iron Age domestic animals, such as pig and cattle, were relied upon heavily, potentially due to the intensification of wet rice farming. Furthermore, the change to a seasonally based lifestyle is demonstrated within the Iron Age bone midden features at BNW and BSL, which are potentially seasonal feasting events. It is unlikely that domestic animals in the Iron Age were bred specifically for burial and mortuary ritual, as the domestic animal remains were found throughout all contexts at all sites, including sites that did not contain burials.

Fish remained a popular resource throughout all time periods at BNW. The majority of fish species were caught in rice fields and ponds, and not by hook and line fishing methods. As the majority of fish species recovered typically inhabit wet rice fields or ponds, this would suggest wet rice fields and later Iron Age moats at BNW were used for aquaculture. Additionally, the sites of BSL and NHR did not have moats and also had limited or no evidence of fishing being practised, with very low numbers of fish identified. Furthermore, the artefactual and faunal remains indicate low levels of occupation at BSL and NHR. This suggests that these sites were seasonally occupied or that they were used for short periods of time for activities such as salt making, hunting, gathering, and clay sourcing.

The results of this thesis support a socio-cultural shift in subsistence towards the use of domestic animals as a food source. However, it is inconclusive as to which current model of social change in Southeast Asia the data supports. There is zooarchaeological evidence to support elements of each model of social change, including the hierarchical model, the heterarchical model, the integrated social and environmental mutual change model, and the ritual feasting model. Additional information on existing models is presented in *Chapter 3*: *Theoretical Approach 3.2 Social Change Theories in Southeast Asia*. The fact that elements of each model are supported, may relate to the overlap within the structure of the models themselves, or suggest that no current model entirely encompasses social change that occurred in the prehistory communities of the Upper Mun River Valley.

This research is part of a movement towards integrating a more holistic approach to the study of zooarchaeology in Southeast Asia. This, in turn, contributes to our understanding of interpretations and changes to subsistence resources in agricultural communities of northeast Thailand and the broader Southeast Asian region

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Appendices

Appendix A: Mandible measurements for *Sus scrofa* from BNW, BSL and NHR

Side	dp_4 L	dp_4 Da	dp_4 Dm	dp_4 Dp	P_4 L	P_4 D	M_1 L	M_1 Da	M_1 Dp	M_2 L	M_2 Da	M_2 Dp	M_3 L	M_3 Da	M_3 Dm	M_3 Dp	Context
L	–	–	–	–	–	–	D	D	D	–	–	–	–	–	–	–	BNW-P300 (GS 7:5)
L	–	–	–	–	–	–	–	–	–	D	D	D	D	D	15.6	13.2	BNW-P300 (F2 Hard floor 3:3
–	–	–	–	–	–	–	–	–	–	D	D	D	–	–	–	–	BNW-P300 (F3 Light brown sandy sediment 3:4)
L	S	S	S	S	D	D	D	D	D	19.84	12.92	13.95	–	–	–	–	BNW-P300 (F2 Channel 3:5)
R	D	7.16	D	D	–	–	–	–	–	–	–	–	–	–	–	–	BNW-S400 (GS 3:3)

L	17.3	7.01	7.97	D	–	–	16.06	10.86	11.98	–	–	–	–	–	–	–	BNW-S400 (GS 3:3)
L	19.06	6.56	7.78	9.11	–	–	–	–	–	–	–	–	–	–	–	–	BNW-S400 (GS 3:7)
L	19.64	6.81	8.36	9.36	–	–	16.19	10.29	11.32	C	C	C	–	–	–	–	BNW-S400 (GS 3:7)
R	S	S	S	S	14.7	10.22	15.93	D	D	20.39	D	D	–	–	–	–	BNW-S400 (GS 3:8)
R	–	–	–	–	–	–	17	10.82	12.71	20.2	12.73	15.82	–	–	–	–	BNW-S400 (GS 3:8)
R	D	D	D	9.07	–	–	–	E	E	–	–	–	–	–	–	–	BNW-S400 (GS 4:2)
L	18.72	6.71	7.75	9.48	–	–	D	11.06	D	22.34	13.45	13.01	C	C	C	C	BNW-S400 (F3 Pit 2:8)
L	D	D	D	9.43	–	–	16.52	11.07	10.79	–	–	–	–	–	–	–	BNW-S400 (F16 Coarse red sandy sediment 4:1)
L	S	S	S	S	15.84	10.73	17.9	11.63	12.31	D	14.72	D	½	½	½	½	BNW-S400 (F8 Pottery and shell concentration 5:1)
L	–	–	–	–	15.96	9.14	14.81	10.99	12.97	20.2	14.23	14.81	34.88	16.45	16.25	13.33	BNW-G104 (GS 4:6)

R	21.31	D	D	9.66	–	–	–	–	–	–	–	–	–	–	–	–	BNW-G104 (GS 5:2)
L	S	S	S	S	E	E	16.61	10.77	11.44	–	–	–	–	–	–	–	BNW-G104 (F6 Brown loam sediment 2:3)
R	20.16	D	D	D	–	–	–	–	–	–	–	–	–	–	–	–	G104 (Burial 645 2:4)
R	19.08	6.09	7.89	9.53	–	–	–	–	–	–	–	–	–	–	–	–	BNW-G104 (F16 Pit 3:2)
R	17.88	6.71	7.64	9.02	–	–	16.81	10.93	12.09	C	C	C	–	–	–	–	BNW-G104 (F25 Pottery concentration 3:4)
R	D	D	D	D	–	–	–	–	–	–	–	–	–	–	–	–	G104 (F23 Shell Midden 4:6)
R	18.46	6.06	7.57	8.03	–	–	–	–	–	–	–	–	–	–	–	–	BNW-N96 (GS 3:4)
L	–	–	–	–	–	–	D	D	11.88	21.18	13.34	13.8	–	–	–	–	BNW-N96 (GS 5:3)
R	–	–	–	–	–	–	–	–	–	–	–	–	32.03	17.1	13.18	11.9	BNW-N96 (GS 5:4)
R	S	S	S	S	14.54	11.17	15.74	10.77	12.01	D	13.7	D	D	D	D	D	BNW-N96 (GS 5:4)

R	–	–	–	–	–	–	–	–	–	–	–	–	V	V	V	V	BNW-N96 (GS 5:4)
R	S	S	S	S	D	D	16.57	10.37	10.94	20.32	13.02	13.88	C	C	C	C	BNW-N96 (F4 Pottery concentration 3:1)
L	S	S	S	S	D	D	16.25	10.25	11.04	19.39	13.16	13.95	C	C	C	C	BNW-N96 (F4 Pottery concentration 3:1)
R	17.22	6.58	7.91	7.58	–	–	–	–	–	–	–	–	–	–	–	–	BNW-N96 (F1 Bone Midden 3:3)
L	–	–	–	–	–	–	–	–	–	18.64	11.37	10.26	C	C	C	C	BNW-N96 (F1 Bone Midden 3:3)
R	S	S	S	S	V	V	16.99	10.39	11.48	19.43	13.48	14.35	–	–	–	–	BNW-N96 (F1 Bone Midden 3:3)
R	D	D	D	D	–	–	D	D	D	–	–	–	–	–	–	–	BNW-N96 (F1 Bone Midden 3:3)
L	17.58	6.41	7.89	8.82	–	–	15.2	D	11.04	–	–	–	–	–	–	–	BNW-N96 (F1 Bone Midden 3:3)

L	17.03	5.66	D	7.51	–	–	15.27	9.4	10.58	–	–	–	–	–	–	–	BNW-N96 (F1 Bone Midden 3:3)
R	D	D	7.5	7.65	–	–	16.76	10.22	10.54	–	–	–	–	–	–	–	BNW-N96 (F1 Bone Midden 3:3)
L	S	S	S	S	12.99	9.62	15.6	9.38	10.34	–	–	–	–	–	–	–	BNW-N96 (F1 Bone Midden 3:3)
R	S	S	S	S	–	–	15.71	10.22	D	19.3	12.07	11.51	C	C	C	C	BNW-N96 (F13 Hard floor 4:1)
R	S	S	S	S	D	D	15.78	10.31	11.04	19.23	12.72	D	C	C	C	C	BNW-N96 (F13 Hard floor 4:1)
L	S	S	S	S	15.48	9.49	15.07	9.6	10.83	19.19	13.2	14.19	½	½	½	½	BNW-N96 (F13 Hard floor 4:1)
R	–	–	–	–	–	–	16.9	10.36	11.44	20.03	13.64	13.39	–	–	–	–	BNW-N96 (F8 Hard floor 4:3.5)
R	S	S	S	S	13.39	8.59	D	D	D	–	–	–	–	–	–	–	BNW-N96 (F3 Pit 5:1)
L	S	S	S	S	13.48	9.17	D	D	D	–	–	–	–	–	–	–	BNW-N96 (F10 Pit 5:1)

L	S	S	S	S	12.56	7.45	–	–	–	–	–	–	–	–	–	–	BNW-N96 (F15 Brown mottled clay sediment 5:5)
R	S	S	S	S	13.92	9.27	–	–	–	–	–	–	–	–	–	–	BNW-N96 (F15 Brown mottled clay sediment 5:5)
L	18.61	6.97	8.2	9.15	–	–	17.5	11.15	12.09	–	–	–	–	–	–	–	BNW-N96 (F12 Coarse red sandy sediment 6:3)
L	–	–	–	–	–	–	–	–	–	–	–	–	28.11	14.25	14.15	9.63	BNW-N96 (F12 Coarse red sandy sediment 6:3)
L	19.46	7.34	7.99	9.8	–	–	V	V	V	–	–	–	–	–	–	–	BNW-N100 (GS 3:1)
–	–	–	–	–	–	–	16.6	10.81	11.98	D	D	D	–	–	–	–	BNW-N100 (GS 7:1)
L	S	S	S	S	D	D	D	D	D	D	D	D	–	–	–	–	BNW-N100 (GS 8:5)
R	18.35	7.05	7.76	9.59	–	–	16.75	10.64	11.98	C	C	C	–	–	–	–	BNW-N100 (GS 8:5)

R	–	–	–	–	–	–	16.88	10.55	12.09	23.81	14.14	16.21	–	–	–	–	BNW-N100 (GS 8:5)
R	D	D	D	8.25	–	–	16.96	10.03	11.25	–	–	–	–	–	–	–	BNW-N100 (F7 Hard floor 2:5)
R	20.06	6.98	7.9	9.58	–	–	–	–	–	–	–	–	–	–	–	–	BNW-N100 (F3 Post hole 2:6)
L	–	–	–	–	–	–	–	D	10.88	D	–	–	–	–	–	–	BNW-N100 (F2 Pit 3:1)
R	–	–	–	–	–	–	–	–	–	–	–	–	34.86	16.66	16.57	14.85	BNW-N100 (F2 Pit 3:1)
R	–	–	–	–	–	–	–	–	–	½	½	½	C	C	C	C	BNW-N100 (F2 Pit 3:1)
L	–	–	–	–	–	–	–	–	–	21.74	13.29	14.32	C	C	C	C	BNW-N100 (F2 Pit 3:1)
L	17.86	6.48	7.53	8.58	–	–	16.2	10.04	11.71	½	½	½	–	–	–	–	BNW-N100 (F1 Hard floor 3:3)
L	19.69	D	D	D	–	–	16.73	D	D	–	–	–	–	–	–	–	BNW-N100 (F2 Post hole 3:5)
R	–	–	–	–	–	–	16.5	10.76	11.97	21.89	D	15.8	–	–	–	–	BNW-N100 (F8 Post hole 4:1)

R	S	S	S	S	D	D	D	D	D	D	16.15	D	–	–	–	–	BNW-N100 (F32 Dark brown mottled clay sediment 7:2)
R	–	–	–	–	–	–	–	–	–	–	–	–	½	½	½	½	BNW-N100 (F2 Post hole 8:1)
L	–	–	–	–	–	–	17.46	10.7	11.89	20.82	13.59	15.4	E	E	E	E	BNW-N100 (F3 Hard floor 8:2)
L	–	–	–	–	–	–	17.51	10.54	12.2	21.57	14.21	16.3	–	–	–	–	BNW-N100 (F4 Pit 8:2)
R	–	–	–	–	–	–	–	–	–	–	–	–	D	D	D	D	BNW-N100 (F8 Hard floor 8:3)
R	–	–	–	–	–	–	–	–	–	–	–	–	35.26	18.07	16.98	13.66	BNW-N100 (F8 Hard floor 8:3)
L	–	–	–	–	–	–	D	D	D	21.47	15.16	16.39	C	C	C	C	BNW-N100 (F6 Shell Midden 9:4)
L	–	–	–	–	–	–	–	–	–	20.8	13.61	13.62	–	–	–	–	BNW-I500 (GS 2:6)

R	S	S	S	S	D	D	D	D	D	D	D	D	–	–	–	–	BNW-IJ500 (F3 Bone concentration 3:11)
L	S	S	S	S	D	D	D	D	D	–	–	–	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
L	D	D	D	D	–	–	D	D	D	–	–	–	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
R	19.75	7.16	D	9.8	–	–	D	D	D	–	–	–	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
L	–	–	–	–	–	–	17.36	D	11.05	–	–	–	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
R	–	–	–	–	–	–	D	D	12.29	–	–	–	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
L	–	–	–	–	–	–	.	.	.	21.62	13.73	13.95	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
L	–	–	–	–	–	–	D	D	11.66	½	½	½	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)

R	–	–	–	–	–	–	.	.	.	20.44	13.28	13.03	C	C	C	C	BNW-K500 (F1 Bone Midden 3:5)
R	–	–	–	–	–	–	16.6	D	11.37	20.48	13.95	14.3	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
L	–	–	–	–	–	–	–	–	–	22.54	13.82	15.95	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
L	–	–	–	–	–	–	D	D	D	D	D	D	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
R	–	–	–	–	–	–	17.01	D	D	22.02	13.22	13.26	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
L	–	–	–	–	–	–	–	–	–	21.06	13.36	14.2	–	–	–	–	BNW-T200 (GS 4:1)
L	–	–	–	–	–	–	17.16	11.04	12.14	20.49	14.46	14.54	–	–	–	–	BNW-T200 (GS 5:5)
L	18.42	D	D	9.14	–	–	17.47	10.3	12.21	–	–	–	–	–	–	–	BNW-T200 (GS 5:6)
R	–	–	–	–	–	–	18	10.53	12	–	–	–	–	–	–	–	BNW-T200 (GS 7:2)

L	–	–	–	–	–	–	17.29	10.21	11.02	19.07	13.33	14.8	–	–	–	–	BNW-T200 (Burial 666 6:1)
L	–	–	–	–	–	–	–	–	–	D	D	D	C	C	C	C	BNW-TU199-200 (GS 6:2)
R	17.51	6.09	7.27	8.56	–	–	16.19	9.9	10.99	C	C	C	–	–	–	–	BNW-TU199-200 (F6 Pit 3:8)
L	D	D	D	D	–	–	–	–	–	–	–	–	–	–	–	–	BNW-TU199-200 (F6 White clay sediment 6:1)
L	S	S	S	S	D	D	–	–	–	–	–	–	–	–	–	–	BNW-U200 (GS 4:3)
L	20.29	7.07	8.29	9.69	–	–	17.6	11.63	12.05	–	–	–	–	–	–	–	BNW-U200 (GS 4:3)
R	–	–	–	–	–	–	17.79	10.9	11.19	21.45	14.68	14.88	C	C	C	C	BNW-U200 (GS 7:1)
L	–	–	–	–	–	–	–	–	–	½	½	½	C	C	C	C	BNW-U200 (F1 Pottery concentration 4:3)

R	S	S	S	S	14.67	9.5	17.47	10.56	12.2	–	–	–	–	–	–	–	BNW-U200 (F1 Pottery concentration 4:3)
L	S	S	S	S	13.38	9.8	16.24	11.81	12.88	20.86	14.12	14.78	–	–	–	–	BNW-U200 (F1 Pottery concentration 4:3)
L	–	–	–	–	–	–	–	–	–	23.02	15.45	15.5	C	C	C	C	BNW-U200 (F1 Pit 6:2)
R	–	–	–	–	–	–	D	D	D	D	D	½	–	–	–	–	BNW- V200 (GS 4:1)
R	D	D	D	D	–	–	–	–	–	–	–	–	–	–	–	–	BNW-V200 (GS 4:3)
R	19.9	7.26	8.27	10.02	–	–	–	–	–	–	–	–	–	–	–	–	BNW- V200 (GS 4:5)
R	S	S	S	S	14.72	10.47	D	D	12.23	20.31	14.95	15.96	–	–	–	–	BNW-V200 (GS 4:7)
L	–	6.8	D	D	–	–	–	–	–	–	–	–	–	–	6.8	D	BNW-V200 (F11 Pottery concentration 4:3)
L	–	–	–	–	–	–	16.6	10.41	11.04	–	–	–	–	–	–	–	BNW-V200 (F2 Pottery

																	concentration 4:4)
L	–	–	–	–	–	–	–	–	–	21.24	13	13.78	–	–	–	–	BNW-V200 (F2 Pottery concentration 4:4)
L	–	–	–	–	–	–	D	D	D	21.18	14.68	15.23	–	–	–	–	BNW-V200 (F2 Pottery concentration 4:4)
L	–	–	–	–	–	–	17.81	10.2	11.97	D	13.48	D	–	–	–	–	BNW-V200 (F2 Pottery concentration 4:4)
R	18.73	6.86	8.67	10.01	–	–	–	–	–	–	–	–	–	–	–	–	BNW-V200 (F9 Pit 5:1)
L	17.96	6.69	7.83	D	–	–	–	–	–	–	–	–	–	–	–	–	BNW-W200 (F14 Hard floor 4:7)
R	D	D	D	7.64	–	–	15.7	10.45	12.24	19.7	12.91	12.96	–	–	–	–	BNW-W200 (F22 Furnace 4:7)
R	–	–	–	–	–	–	18.74	11.2	12.63	D	15.29	D	–	–	–	–	BNW-W200 (F4 Pit 5:4)

L	–	–	–	–	–	–	17.03	10.96	12.74	D	14.71	D	–	–	–	–	BNW-W200 (F4 Pit 7:1)
L	19	6.63	8.4	9.12	–	–	16.77	10.72	12.05	–	–	–	–	–	–	–	BNW-W200 (F5 Pit 7:1)
L	18.21	6.3	7.84	8.81	–	–	15.33	9.76	11.19	–	–	–	–	–	–	–	BNW-Z201 (GS 3:4)
R	18.59	6.81	7.32	8.82	–	–	–	–	–	–	–	–	–	–	–	–	BNW-Z201 (GS 4:1)
R	–	–	–	–	–	–	15.66	9.92	10.9	18.02	12.45	12.99	C	C	C	C	BNW-Z201 (GS 5:1)
L	–	–	–	–	–	–	18.19	11.59	13.19	22.6	15.22	15.53	–	–	–	–	BNW-Z201 (GS 5:1)
R	19.97	6.91	7.58	9.54	–	–	17.21	D	12.67	–	–	–	–	–	–	–	BNW-Z201 (F1 Post hole 4:1)
R	–	–	–	–	–	–	D	D	D	22.72	14.72	15.74	–	–	–	–	BNW-Z201 (F11 Coarse red sandy sediment 4:3)
R	–	–	–	–	–	–	16.8	D	13.78	20.34	14.13	16.15	–	–	–	–	BSL-M100 (GS 3:2)
R	–	–	–	–	–	–	16.14	10.11	D	–	–	–	–	–	–	–	BSL-M100 (GS 3:3)

R	S	S	S	S	14.45	D	D	–	–	–	–	–	–	–	–	–	BSL-M100 (GS 4:1)
R	–	–	–	–	–	–	D	D	D	C	C	C	–	–	–	–	BSL-M100 (GS 4:2)
R	–	–	–	–	–	–	15.85	9.71	10.61	19.84	12.94	13.71	–	–	–	–	BSL-M100 (F34 Pottery Concentration 2:1)
R	–	–	–	–	–	–	–	–	–	D	D	D	½	12.92	D	D	BSL-M100 (F160 Pit 3:3)
L	D	D	D	9.01	–	–	18.05	11.21	12.13	–	–	–	–	–	–	–	BSL-M100 (F176 Sandy sediment 3:3)
R	–	–	–	–	–	–	17.66	10.57	11.99	–	–	–	–	–	–	–	BSL-M100 (F187 Bone Midden 5:1)
L	20.58	7.52	8.51	9.87	–	–	D	11.38	–	–	–	–	–	–	–	–	NHR-HI100 (GS 3:15)

R	S	S	S	S	D	D	D	D	D	–	–	–	–	–	–	–	NHR-I100 (F8 Hard floor 3:3)
L	19.02	6.91	8.18	10.05	–	–	–	–	–	–	–	–	–	–	–	–	NHR-H100 (F6 Dark sediment 3:6)
R	D	D	7.05	9.2	–	–	–	–	–	–	–	–	–	–	–	–	NHR-HI100 (F13 Hard floor 3:12)

C-Perforation in crypt visible
V-Tooth visible in crypt but below head of bone
E-Tooth erupting through bone
½-Tooth half erupted
U-Tooth almost at full height but unworn
D-Damaged
S-Shed

Appendix B: Mandible tooth wear stage for *Sus scrofa* from BNW, BSL and NHR

dp_4 Wear	P_4 Wear	M_1 Wear	M_2 Wear	M_3 Wear	Age class	Age stages	Context
–	–	d	–	–	IV	Young sub-adult	BNW-P300 (GS 7:5)
–	–	–	f	c	VI	Adult	BNW-P300 (F2 Hard floor 3:3
–	–	–	a	–	IV	Young sub-adult	BNW-P300 (F3 Light brown sandy sediment 3:4)
S	D	D	c	–	IV	Young sub-adult	BNW-P300 (F2 Channel 3:5)
m	–	–	–	–	III	Juvenile	BNW-S400 (GS 3:3)
m	–	c	–	–	III	Juvenile	BNW-S400 (GS 3:3)
d	–	–	–	–	II	Infant	BNW-S400 (GS 3:7)
e	–	a	C	–	II	Infant	BNW-S400 (GS 3:7)
S	d	j	h	–	VI	Adult	BNW-S400 (GS 3:8)
–	–	e	c	–	IV	Young sub-adult	BNW-S400 (GS 3:8)
d	–	E	–	–	II	Infant	BNW-S400 (GS 4:2)
g	–	b	½	–	III	Juvenile	BNW-S400 (F3 Pit 2:8)
e	–	U	–	–	II	Infant	BNW-S400 (F16 Coarse red sandy sediment 4:1)
S	c	d	c	½	IV	Young sub-adult	BNW-S400 (F8 Pottery and shell concentration 5:1)
–	f	n	l	b	VII	Old adult	BNW-G104 (GS 4:6)
c	–	–	–	–	I	Newborn	BNW-G104 (GS 5:2)
S	E	c	–	–	III	Juvenile	BNW-G104 (F6 Brown loam sediment 2:3)
b	–	–	–	–	I	Newborn	G104 (Burial 645 2:4)

b	–	–	–	–	I	Newborn	BNW-G104 (F16 Pit 3:2)
h	–	a	C	–	III	Juvenile	BNW-G104 (F25 Pottery concentration 3:4)
D	–	–	–	–	–	–	G104 (F23 Shell Midden 4:6)
d	–	–	–	–	II	Infant	BNW-N96 (GS 3:4)
–	–	–	e	c	VI	Adult	BNW-N96 (GS 5:3)
–	–	–	–	c	VI	Adult	BNW-N96 (GS 5:4)
S	b	f	e	D	V	Sub-adult	BNW-N96 (GS 5:4)
–	–	–	–	V	IV	Young sub-adult	BNW-N96 (GS 5:4)
S	D	d	a	C	IV	Young sub-adult	BNW-N96 (F4 Pottery concentration 3:1)
S	D	d	a	C	IV	Young sub-adult	BNW-N96 (F4 Pottery concentration 3:1)
D	–	D	–	–	–	–	BNW-N96 (F1 Bone Midden 3:3)
e	–	–	–	–	II	Infant	BNW-N96 (F1 Bone Midden 3:3)
–	–	–	½	C	III	Juvenile	BNW-N96 (F1 Bone Midden 3:3)
k	–	a	–	–	III	Juvenile	BNW-N96 (F1 Bone Midden 3:3)
m	–	b	–	–	III	Juvenile	BNW-N96 (F1 Bone Midden 3:3)
l	–	U	–	–	III	Juvenile	BNW-N96 (F1 Bone Midden 3:3)
S	b	d	–	–	IV	Sub-adult	BNW-N96 (F1 Bone Midden 3:3)
S	V	d	U	–	IV	Sub-adult	BNW-N96 (F1 Bone Midden 3:3)
S	D	e	a	C	IV	Young sub-adult	BNW-N96 (F13 Hard floor 4:1)

S	D	D	a	C	IV	Young sub-adult	BNW-N96 (F13 Hard floor 4:1)
S	a	e	c	½	IV	Young sub-adult	BNW-N96 (F13 Hard floor 4:1)
–	–	g	c	–	V	Sub-adult	BNW-N96 (F8 Hard floor 4:3.5)
S	b	D	–	–	IV	Young sub-adult	BNW-N96 (F3 Pit 5:1)
S	g	D	–	–	VII	Old adult	BNW-N96 (F10 Pit 5:1)
S	b	–	–	–	IV	Young sub-adult	BNW-N96 (F15 Brown mottled clay sediment 5:5)
S	c	–	–	–	IV	Young sub-adult	BNW-N96 (F15 Brown mottled clay sediment 5:5)
j	–	c	–	–	III	Juvenile	BNW-N96 (F12 Coarse red sandy sediment 6:3)
–	–	–	–	½	V	Sub-adult	BNW-N96 (F12 Coarse red sandy sediment 6:3)
b	–	V	–	–	I	Newborn	BNW-N100 (GS 3:1)
–	–	h	e	–	V	Sub-adult	BNW-N100 (GS 7:1)
S	D	D	D	–	–	–	BNW-N100 (GS 8:5)
k	–	c	C	–	III	Juvenile	BNW-N100 (GS 8:5)
–	–	e	a	–	IV	Young sub-adult	BNW-N100 (GS 8:5)
m	–	b	–	–	III	Juvenile	BNW-N100 (F7 Hard floor 2:5)
e	–	–	–	–	II	Infant	BNW-N100 (F3 Post hole 2:6)
–	–	–	–	d	VI	Adult	BNW-N100 (F2 Pit 3:1)
–	–	a	–	–	II	Infant	BNW-N100 (F2 Pit 3:1)

–	–	–	½	C	III	Juvenile	BNW-N100 (F2 Pit 3:1)
–	–	–	a	C	IV	Young sub-adult	BNW-N100 (F2 Pit 3:1)
l	–	b	½	–	III	Juvenile	BNW-N100 (F1 Hard floor 3:3)
l	–	b	–	–	III	Juvenile	BNW-N100 (F2 Post hole 3:5)
–	–	h	e	–	V	Sub-adult	BNW-N100 (F8 Post hole 4:1)
S	D	D	h	–	VI	Adult	BNW-N100 (F32 Dark brown mottled clay sediment 7:2)
–	–	–	–	½	V	Sub-adult	BNW-N100 (F2 Post hole 8:1)
–	–	d	b	E	IV	Young sub-adult	BNW-N100 (F3 Hard floor 8:2)
–	–	d	a	–	IV	Young sub-adult	BNW-N100 (F4 Pit 8:2)
–	–	–	–	D	–	–	BNW-N100 (F8 Hard floor 8:3)
–	–	–	–	a	v	Sub-adult	BNW-N100 (F8 Hard floor 8:3)
–	–	g	c	C	V	Sub-adult	BNW-N100 (F6 Shell Midden 9:4)
–	–	–	U	–	III	Juvenile	BNW-I500 (GS 2:6)
S	D	D	D	–	–	–	BNW-IJ500 (F3 Bone concentration 3:11)
S	D	D	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
D	–	D	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
e	–	D	–	–	II	Infant	BNW-K500 (F1 Bone Midden 3:5)
–	–	a	–	–	II	Infant	BNW-K500 (F1 Bone Midden 3:5)
–	–	a	–	–	II	Infant	BNW-K500 (F1 Bone Midden 3:5)

–	–	–	U	–	III	Juvenile	BNW-K500 (F1 Bone Midden 3:5)
–	–	c	½	–	III	Juvenile	BNW-K500 (F1 Bone Midden 3:5)
–	–	–	U	C	III	Juvenile	BNW-K500 (F1 Bone Midden 3:5)
–	–	g	c	–	V	Sub-adult	BNW-K500 (F1 Bone Midden 3:5)
–	–	–	b	–	IV	Young sub-adult	BNW-K500 (F1 Bone Midden 3:5)
–	–	d	D	–	IV	Young sub-adult	BNW-K500 (F1 Bone Midden 3:5)
–	–	e	a	–	IV	Young sub-adult	BNW-K500 (F1 Bone Midden 3:5)
–	–	–	c	–	IV	Young sub-adult	BNW-T200 (GS 4:1)
–	–	c	a	–	IV	Young sub-adult	BNW-T200 (GS 5:5)
h	–	U	–	–	III	Juvenile	BNW-T200 (GS 5:6)
–	–	b	–	–	III	Juvenile	BNW-T200 (GS 7:2)
–	–	d	b	–	IV	Young sub-adult	BNW-T200 (Burial 666 6:1)
–	–	–	D	C	–	–	BNW- TU199-200 (GS 6:2)
m	–	b	C	.	III	Juvenile	BNW- TU199-200 (F6 Pit 3:8)
D	–	–	–	–	–	–	BNW- TU199-200 (F6 White clay sediment 6:1)
S	D	–	–	–	–	–	BNW-U200 (GS 4:3)
k	–	c	–	–	III	Juvenile	BNW-U200 (GS 4:3)
–	–	c	a	C	III	Juvenile	BNW-U200 (GS 7:1)
–	–	–	½	C	III	Juvenile	BNW-U200 (F1 Pottery concentration 4:3)

S	a	e	–	–	IV	Sub-adult	BNW-U200 (F1 Pottery concentration 4:3)
S	c	h	b	–	V	Sub-adult	BNW-U200 (F1 Pottery concentration 4:3)
–	–	–	b	–	IV	Young sub-adult	BNW-U200 (F1 Pit 6:2)
–	–	d	½	–	IV	Young sub-adult	BNW- V200 (GS 4:1)
K	–	–	–	–	III	Juvenile	BNW-V200 (GS 4:3)
j	–	–	–	–	III	Juvenile	BNW- V200 (GS 4:5)
S	a	e	a	–	IV	Young sub-adult	BNW-V200 (GS 4:7)
a	–	–	–	–	I	Newborn	BNW-V200 (F11 Pottery concentration 4:3)
–	–	c	–	–	III	Juvenile	BNW-V200 (F2 Pottery concentration 4:4)
–	–	–	U	–	III	Juvenile	BNW-V200 (F2 Pottery concentration 4:4)
–	–	b	b	–	IV	Young sub-adult	BNW-V200 (F2 Pottery concentration 4:4)
–	–	e	a	–	IV	Young sub-adult	BNW-V200 (F2 Pottery concentration 4:4)
m	–	–	–	–	III	Juvenile	BNW-V200 (F9 Pit 5:1)
e	–	–	–	–	II	Infant	BNW-W200 (F14 Hard floor 4:7)
m	–	b	U	–	III	Juvenile	BNW-W200 (F22 Furnace 4:7)
–	–	f	a	–	V	Sub-adult	BNW-W200 (F4 Pit 5:4)
–	–	b	a	–	IV	Young sub-adult	BNW-W200 (F4 Pit 7:1)

g	–	a	–	–	III	Juvenile	BNW-W200 (F5 Pit 7:1)
E	–	b	–	–	III	Juvenile	BNW-Z201 (GS 3:4)
d	–	–	–	–	II	Infant	BNW-Z201 (GS 4:1)
–	–	c	U	C	III	Juvenile	BNW-Z201 (GS 5:1)
–	–	c	–	–	III	Juvenile	BNW-Z201 (GS 5:1)
j	–	b	–	–	III	Juvenile	BNW-Z201 (F1 Post hole 4:1)
–	–	D	b	–	IV	Young sub-adult	BNW-Z201 (F11 Coarse red sandy sediment 4:3)
–	–	d	a	–	IV	Young sub-adult	BSL-M100 (GS 3:2)
–	–	b	–	–	III	Juvenile	BSL-M100 (GS 3:3)
–	a	–	–	–	IV	Young sub-adult	BSL-M100 (GS 4:1)
–	–	D	C	–	III	Juvenile	BSL-M100 (GS 4:2)
–	–	e	U	–	IV	Young sub-adult	BSL-M100 (F34 Pottery Concentration 2:1)
–	–	–	D	½	V	Sub-adult	BSL-M100 (F160 Pit 3:3)
k	–	a	–	–	III	Juvenile	BSL-M100 (F176 Sandy sediment 3:3)
–	–	c	–	–	III	Juvenile	BSL-M100 (F187 Bone Midden 5:1)
c	–	a	–	–	II	Infant	NHR-HI100 (GS 3:15)
S	D	d	–	–	IV	Young sub-adult	NHR-I100 (F8 Hard floor 3:3)
d	–	–	–	–	II	Indant	NHR-H100 (F6 Dark sediment 3:6)
e	–	–	–	–	II	Indant	NHR-HI100 (F13 Hard floor 3:12)

a to n- Tooth wear stages for pig (From: Grant 1982:92)
C-Perforation in crypt visible

V-Tooth visible in crypt but below head of bone
E-Tooth erupting through bone
½-Tooth half erupted
U-Tooth almost at full height but unworn
D-Damaged
S-Shed

Appendix C: Mandible measurements for *Canis* genus from BNW and BSL

Side	M_1-M_3 L	dp_4 L	dp_4 Da	dp_4 Dp	P_4 L	P_4 D	M_1 L	M_1 Da	M_1 Dp	M_2 L	M_2 D	Context
L	–	–	–	–	–	–	–	–	–	9.2	6.4	BNW-S400 (GS 2:10)
R	–	S	S	S	D	D	–	–	–	–	–	BNW-S400 (GS 4:2)
R	–	–	–	–	10.63	6.17	–	–	–	9.37	7.37	BNW-S400 (F10 Pit 2:12)
R	–	–	–	–	–	–	18.57	7.67	7.51	8.73	6.9	BNW-S400 (F16 Coarse red sandy sediment 4:1)
L	–	D	D	D	–	–	D	D	D	–	–	BNW-G104 (F2 Dog burial 7:3)
R	–	D	D	D	–	–	D	D	D	–	–	BNW-G104 (F2 Dog burial 7:3)
R	–	S	S	S	D	D	19.36	8.72	8.07	9.04	7.83	BNW-N96 (F1 Bone Midden 3:3)

L	–	S	S	S	11.24	5.93	20.08	8.65	7.99	D	D	BNW- N96 (F3 Pit 5:1)
L	68.71	S	S	S	11.2	6.27	21.13	9.47	8.85	9.12	7.86	BNW-N96 (F14 Post hole with two dog skulls 5:2)
R	–	S	S	S	D	D	D	D	8.81	9.1	7.84	BNW-N96 (F14 Post hole with two dog skulls 5:2)
L	–	D	D	D	–	–	17.8	8.38	6.8	8.38	5.87	BNW-N96 (F14 Post hole with two dog skulls 5:2)
R	–	D	D	D	–	–	D	D	D	D	D	BNW-N96 (F14 Post hole with two dog skulls 5:2)
R	–	–	–	–	–	–	–	–	–	9.07	7.11	BNW-N100 (GS 3:2)
L	–	–	–	–	–	–	19.7	D	D	D	D	BNW-N100 (GS 7:1)
L	–	–	–	–	–	–	–	–	–	8.86	6.77	BNW-N100 (GS 8:5)

R	–	–	–	–	–	–	19.59	D	D	D	–	BNW-N100 (GS 8:5)
L	–	S	S	S	9.8	5.39	–	–	–	–	–	BNW-N100 (GS 8:5)
L	–	–	–	–	–	–	18.06	10.17	8.44	–	–	BNW-N100 (GS 8:5)
R	–	S	S	S	D	D	19.17	9.6	9.47	9.16	D	BNW-N100 (F17 Pit with dog skulls 3:8)
L	–	S	S	S	D	D	D	D	D	D	D	BNW-N100 (F17 Pit with dog skulls 3:8)
R	–	–	–	–	–	–	20.79	8.08	8.86	–	–	BNW-N100 (F32 Dark brown mottled clay sediment 7:2)
R	–	–	–	–	9.11	D	D	D	D	8.38	6.15	BNW-N100 (Burial 667 7:3)
R	–	S	S	S	–	–	–	–	–	–	–	BNW-K500 (F1 Bone Midden 3:5)

R	–	–	–	–	–	–	19.82	8.64	8.15	9.42	8.41	BNW-T200 (GS 5:2)
L	–	–	–	–	–	–	–	–	–	8.15	6.5	BNW-T200 (GS 7:1)
L	75	S	S	S	11.56	7.13	21.53	9.31	8.67	9.12	7.46	BNW-W200 (F1 Dog burial 5:3)
R	75.14	S	S	S	11.58	7.14	21.53	9.37	8.72	9.16	7.45	BNW-W200 (F1 Dog burial 5:3)
L	–	S	S	S	13.93	7.06	–	–	–	–	–	BNW-Z201 (GS 4:5)
R	–	S	S	S	12.42	6.64	22.69	9.5	9.33	10.57	7.87	BSL-M100 (GS 6:1)
R	–	–	–	–	–	–	–	–	–	9.5	8.17	BSL-M100 (F187 Bone Midden 5:1)

S-Shed
D-Damaged

Appendix D: The metacarpal measurements for *Bubalus* and *Bos* from BNW

Bone Element (ID)	Length	Prox.W	Dist. W	Context
Left metacarpal (*Bubalus*)	–	73.66	–	BNW-P300 (F1 Hard floor 3:2)
Right metacarpal (*Bubalus*)	–	71.07	–	BNW-P300 (F3 Channel 3:5)
Left metacarpal (*Bubalus*)	–	85.25	–	BNW-S400 (GS 3:6)
Left metacarpal (*Bos*)	–	–	59.35	BNW-S400 (GS 3:8)
Right metacarpal (*Bos*)	222.08	–	57.34	BNW-G104 (GS 3:3)
Right metacarpal (*Bos*)	–	–	52.81	BNW-G104 (GS 4:3)
Right metacarpal (*Bos*)	–	52.27	–	BNW-N96 (GS 5:4)
Left metacarpal (*Bos*)	–	59.1	–	BNW-N96 (GS 6:3)
Right metacarpal (*Bos*)	–	54.9	–	BNW-N96 (GS 6:8)
Right metacarpal (*Bubalus*)	188.26	64.39	74.91	BNW-N96 (F1 Bone Midden 3:3)
Left metacarpal (*Bubalus*)	160.7	61.87	69.48	BNW-N96 (F1 Bone Midden 3:3)
Right metacarpal (*Bubalus*)	–	71.85	–	BNW-N96 (F1 Bone Midden 3:3)
Right metacarpal (*Bubalus*)	182.95	71.3	81.95	BNW-N96 (F1 Bone Midden 3:3)
Right metacarpal (*Bubalus*)	–	74.95	–	BNW-N96 (F1 Bone Midden 3:3)
Metacarpal (*Bubalus*)	–	–	71.79	BNW-N96 (F11 Hard floor 4:3)
Left metacarpal (*Bos*)	–	–	60.65	BNW-N96 (F5 Pottery concentration 4:6)
Right metacarpal (*Bos*)	–	46.58	–	BNW-N96 (F15 Brown mottled clay sediment 5:5)
Right metacarpal (*Bos*)	–	45.21	–	BNW-N96 (F15 Brown mottled clay sediment 5:5)
Metacarpal (*Bubalus*)	–	–	67.18	BNW-N100 (GS 2:5)
Left metacarpal (*Bubalus*)	–	68.12	–	BNW-I500 (F1 Hard floor 3:6)
Right metacarpal (*Bubalus*)	–	–	80.04	BNW-K500 (F2 Channel 3:4)
Left metacarpal (*Bos*)	–	68.01	–	BNW-K500 (F1 Bone Midden 3:5)

Left metacarpal (*Bubalus*)	–	–	73.76	BNW-K500 (F1 Bone Midden 3:5)
Left metacarpal (*Bos*)	–	68.52	–	BNW-K500 (F1 Bone Midden 3:5)
Right metacarpal (*Bubalus*)	–	71.49	–	BNW-K500 (F1 Bone Midden 3:5)
Right metacarpal (*Bubalus*)	–	–	80.88	BNW-K500 (F1 Bone Midden 3:5)
Left metacarpal (*Bos*)	–	49.59	–	BNW-K500 (F1 Bone Midden 3:5)
Right metacarpal (*Bubalus*)	–	65.84	–	BNW-K500 (F1 Bone Midden 3:5)
Left metacarpal (*Bos*)	–	49.95	–	BNW-K500 (F1 Bone Midden 3:5)
Left metacarpal (*Bubalus*)	188.19	68.9	80.57	BNW-K500 (F1 Bone Midden 3:5)
Left metacarpal (*Bos*)	–	–	53.49	BNW-T200 (GS 7:2)
Left metacarpal (*Bos*)	–	64.21	–	BNW-V200 (GS 3:3)
Right metacarpal (*Bos*)	–	–	63.02	BNW-V200 (GS 5:2)
Metacarpal (*Bos*)	–	–	50.16	BNW-V200 (F12 Pottery concentration 4:6)
Left metacarpal (*Bubalus*)	–	77.39		BNW-Z201 (GS 5:2)
Right metacarpal (*Bos*)	234.26	61	62.04	BNW-Z201 (F3 Pottery concentration 5:1)
Left metacarpal (*Bubalus*)	–	–	96.87	BNW-Z201 (F4 Pit 5:4)
Metacarpal *Bubalus bubalis*	183.4	62.5	74.2	Thailand ♀ *n* = 24 (Higham 1975)
Metacarpal *Bos taurus*	195.9	54.7	58.8	Thailand ♀ *n* = 18 (Higham 1975)
Metacarpal *Bos gaurus*	224.75	62.1	61	♀ *n* = 2 (Higham 1975)
Metacarpal *Bos gaurus*	228	73.5	69.75	♂ *n* = 2 (Higham 1975)
Metacarpal *Bos javanicus*	239.5	53	54.5	Java ♀ *n* = 2 (Higham 1975)
Metacarpal *Bos javanicus*	266	60	63.33	Java ♂ *n* = 3 (Higham 1975)

Appendix E: The metatarsal measurements for *Bubalus* and *Bos* from BNW

Bone Element (ID)	Length	Prox.W	Dist. W	Context
Left Metatarsal (*Bubalus*)	–	53.89	–	BNW-P300 (GS 3:2)
Right Metatarsal (*Bos*)	–	–	63.77	BNW-P300 (F1 Hard floor 3:2)
Right Metatarsal (*Bubalus*)	–	54.1	–	BNW-P300 (F10 Dark brown sediment 3:3)
Metatarsal (*Bubalus*)	–	–	71.22	BNW-P300 (F10 Dark brown sediment 3:3)
Left Metatarsal (*Bubalus*)	–	–	69.53	BNW-P300 (Feature2 Channel 3:5)
Right Metatarsal (*Bubalus*)	–	–	73.64	BNW-S400 (F1 Hard floor 2:1)
Right Metatarsal (*Bos*)	–	58.5	–	BNW-S400 (F8 Pit 2:11)
Left Metatarsal (*Bos*)	–	47.86	–	BNW-S400 (F6 Post hole 3:5)
Right Metatarsal (*Bos*)	–	48.28	–	BNW-S400 (F8 Pottery and shell concentration 5:1)
Metatarsal (*Bos*)	–	–	53.27	BNW-G104 (F8 Pottery concentration 2:5)
Left Metatarsal (*Bubalus*)	–	53.37	_	BNW-N96 (F1 Bone Midden 3:3)
Left Metatarsal (*Bubalus*)	–	–	67.03	BNW-N96 (F1 Bone Midden 3:3)
Right Metatarsal (*Bubalus*)	–	–	65.64	BNW-N96 (F1 Bone Midden 3:3)
Left Metatarsal (*Bubalus*)	218.36	60.25	73.12	BNW-N96 (F1 Bone Midden 3:3)
Right Metatarsal (*Bubalus*)	198.6	–	69.7	BNW-N96 (F1 Bone Midden 3:3)
Left Metatarsal (*Bubalus*)	–	57.34	–	BNW-N96 (F1 Bone Midden 3:3)
Right Metatarsal (*Bubalus*)	–	58.09	–	BNW-N96 (F1 Bone Midden 3:3)
Left Metatarsal (*Bubalus*)	_	55.01	–	BNW-N96 (F11 Hard floor Midden 4:3)
Right Metatarsal (*Bos*)	–	–	58.45	BNW-N96 (F25 Orange sandy sediment 6:6)
Left Metatarsal (*Bos*)	–	–	56.66	BNW-N96 (F28 Grey clay sediment 6:6)
Right Metatarsal (*Bubalus*)	–	60.7	–	BNW-N100 (GS 2:2)
Left Metatarsal (*Bos*)	–	–	63.71	BNW-J500 (GS 2:11)
Left Metatarsal (*Bos*)	–	–	52.24	BNW-K500 (F1 Bone Midden 3:5)

Left Metatarsal (*Bubalus*)	–	64.85	–	BNW-K500 (F1 Bone Midden 3:5)
Right Metatarsal (*Bos*)	–	43.72	–	BNW-T200 (GS 6:2)
Left Metatarsal (*Bos*)	–	50.99	–	BNW-T200 (F9 Post hole 2:3)
Left Metatarsal (*Bos*)	–	46.66	–	BNW-TU199-200(GS 6:2)
Left Metatarsal (*Bos*)	–	56.53	–	BNW-U200 (F30 Pottery concentration 7:3)
Right Metatarsal (*Bos*)	–	–	52.97	BNW-Z201 (GS 4:5)
Left Metatarsal (*Bos*)	–	45.61	–	BNW-Z201 (GS 5:1)
Metatarsal *Bubalus bubalis*	221.9	55.0	69.7	Thailand ♀ *n* = 21 (Higham 1975)
Metatarsal *Bos gaurus*	254.5	52.5	57.75	♀ *n* = 2 (Higham 1975)
Metatarsal *Bos gaurus*	275	60.05	65.5	♂ *n* = 2 (Higham 1975)
Metatarsal *Bos javanicus*	246.33	54	55	♀ *n* = 3 (Higham 1975)
Metatarsal *Bos javanicus*	269	60.5	64.25	♂ *n* = 4 (Higham 1975)

Appendix F: Magnum measurements for *Bubalus* and *Bos* from BNW

Bone Element (ID)	Length	Max. W	Max. D	Context
Right magnum (*Bubalus*)	22.61	38.37	40.25	BNW-P300 (F1 Channel 3:5)
Left magnum (*Bos*)	20.6	34.66	31.67	BNW-G104 (GS 4:1)
Left magnum (*Bubalus*)	21.53	38.78	41.58	BNW-N96 (F1 Bone Midden 3:3)
Right magnum (*Bubalus*)	23.05	38.81	41.24	BNW-N96 (F1 Bone Midden 3:3)
Right magnum (*Bubalus*)	22.4	38.64	41.35	BNW-N96 (F1 Bone Midden 3:3)
Right magnum (*Bubalus*)	22.77	37.77	41.19	BNW-K500 (F1 Hard floor 3:1)
Left magnum (*Bubalus*)	23.65	39.36	46.28	BNW-K500 (F1 Bone Midden 3:5)
Left magnum (*Bubalus*)	22.77	39.33	41.39	BNW-K500 (F1 Bone Midden 3:5)
Right magnum (*Bubalus*)	22.03	38.95	43.72	BNW-K500 (F1 Bone Midden 3:5)
Left magnum (*Bubalus*)	25.33	41.09	45.5	BNW-K500 (F1 Bone Midden 3:5)
Left magnum (*Bos*)	22.55	38.71	36.59	BNW-T200 (GS 1:4)
Left magnum (*Bos*)	21.34	32.61	32	BNW-T200 (GS 2:1)
Right magnum (*Bos*)	19.02	36.26	31.89	BNW-T200 (GS 2:1)
Magnum *Bubalus bubalis*	–	36.9	39.7	♀ *n* = 15 (Higham 1975)
Magnum *Bos taurus*	–	37.4	30.5	*n* = 5 (Higham 1975)
Magnum *Bos gaurus*	–	48.4	42.3	(Higham 1975)
Magnum *Bos javanicus*	–	40.5	39	♂ (Higham 1975)

Appendix G: The first phalanx measurements for *Bubalus* and *Bos* from BNW

Bone Element (ID)	Length	Prox.W	Dist. W	Min. W	Context
1st phalanx (*Bubalus*)	66.7	33.33	30.81	28.91	BNW-P300 (GS 2:2)
1st hind phalanx (*Bos*)	68.92	33.59	32.17	29.36	BNW-P300 (GS 6:1)
1st phalanx (*Bubalus*)	76.01	40.26	37.98	–	BNW-P300 (F10 Dark brown sediment 3:3)
1st phalanx (*Bubalus*)	77.74	36.78	36.72	35.38	BNW-P300 (F10 Dark brown sediment 3:3)
1st phalanx (*Bubalus*)	–	–	36.02	–	BNW-P300 (F10 Dark brown sediment 3:3)
1st phalanx (*Bubalus*)	77.98	37.85	36.66	34.93	BNW-P300 (F3 Channel 3:5)
1st phalanx (*Bubalus*)	67.17	36.97	38.31	35.82	BNW-P300 (F1 Channel 3:5)
1st phalanx (*Bos*)	73.08	39.35	37.65	–	BNW-P300 (F1 Channel 3:5)
1st phalanx (*Bos*)	55.13	–	–	–	BNW-S400 (GS 4:2)
1st phalanx (*Bos*)	60.78	28.88	26.52	25.78	BNW-S400 (F1 Pit 3:2)
1st phalanx (*Bos*)	–	–	26.72	–	BNW-G104 (GS 1:6)
1st phalanx (*Bos*)	77.25	31.06	28.77	28.77	BNW-G104 (GS 4:6)
1st phalanx (*Bos*)	67.82	28.08	26.36	27.86	BNW-G104 (F6 Brown loam sediment 2:3)
1st phalanx (*Bos*)	50.45	20.23	18.35	18.35	BNW-G104 (F14 Brown loam sediment 4:5)
1st phalanx (*Bos*)	76.52	33.95	32.06	31.64	BNW-G104 (F23 Shell Midden 4:6)
1st phalanx (*Bos*)	–	–	21.25	–	BNW-N96 (GS 2:2)
1st phalanx (*Bos*)	55.81	23.25	19.69	19.69	BNW-N96 (GS 2:2)
1st phalanx (*Bos*)	74.23	37.66	35.76	35.76	BNW-N96 (GS 3:3)
1st phalanx (*Bubalus*)	–	35	–	–	BNW-N96 (GS 4:2)
1st phalanx (*Bos*)	67.09	28.52	24.67	24.64	BNW-N96 (GS 5:1)

1st phalanx (*Bos*)	57.94	–	23.96	23.73	BNW-N96 (GS 5:3)
1st phalanx (*Bos*)	–	52.27	26.1	25.72	BNW-N96 (GS 5:4)
1st phalanx (*Bos*)	59.58	24.84	21.84	21.84	BNW-N96 (F7 Pottery concentration 3:1)
1st phalanx (*Bubalus*)	72.68	36.13	35.45	34.45	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bubalus*)	64.75	35.79	34.21	33.34	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bos*)	66.26	28.74	26.62	26.27	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bubalus*)	66.94	37.36	34.84	34.41	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bubalus*)	68.45	36.74	35.68	34.32	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bubalus*)	71.19	35.65	32.3	31.26	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bubalus*)	75.08	38.54	29.21	35.57	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bubalus*)	62.77	31.02	32.56	32.05	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bos*)	65.48	29.67	27.96	27.34	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bubalus*)	71.55	37.11	31.22	31.20	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bubalus*)	–	36.23	–	–	BNW-N96 (F1 Bone Midden 3:3)
1st phalanx (*Bos*)	–	28.16	–	–	BNW-N96 (F6 Hard floor 4:3)
1st phalanx (*Bos*)	–	24.25	–	–	BNW-N96 (F25 Pottery concentration 4:4)
1st phalanx (*Bos*)	73.32	–	28.52	–	BNW-N96 (F11 Hard floor 4:7)
1st phalanx (*Bos*)	–	–	24.73	24.14	BNW-N96 (F11 Pit 5:1)
1st phalanx (*Bos*)	–	–	25.42	–	BNW-N96 (F19 Coarse red sandy sediment 6:2)
1st phalanx (*Bos*)	55.45	–	23.54	23.54	BNW-N96 (F12 Coarse red sandy sediment 6:3)
1st phalanx (*Bos*)	–	–	22.9	–	BNW-N96 (F13 Grey clay sediment 6:3)
1st phalanx (*Bos*)	–	24.4	–	–	BNW-N96 (F13 Grey clay sediment 6:3)

1st phalanx (*Bos*)	74.39	25.4	27.58	26.99	BNW-N96 (Burial 688 6:7)
1st hind phalanx (*Bos*)	67.71	25.47	25.04	25.04	BNW-N100 (GS 7:1)
1st phalanx (*Bubalus*)	–	–	38.64	–	BNW-N100 (GS 7:3)
1st phalanx (*Bubalus*)	–	–	36.31	–	BNW-N100 (GS 8:1)
1st phalanx (*Bubalus*)	88.29	44.52	40.16	36.76	BNW-N100 (GS 8:5)
1st phalanx (*Bubalus*)	90.85	41.32	40.74	28.76	BNW-N100 (GS 8:6)
1st phalanx (*Bos*)	56.84	–	22.82	–	BNW-N100 (F2 Pit 3:1)
1st phalanx (*Bos*)	64.64	28.2	–	–	BNW-N100 (F27 Post hole 3:5)
1st phalanx (*Bubalus*)	–	42.62	–	–	BNW-N100 (Burial 661 7:1)
1st phalanx (*Bubalus*)	–	–	40.33	–	BNW-N100 (F33 Dark brown sediment 7:2)
1st phalanx (*Bos*)	67.12	32.58	31.08	30.5	BNW-N100 (F8 Hard floor 8:3)
1st phalanx (*Bos*)	78.17	30.91	27.26	27.2	BNW-N100 (F1 Channel 9:2)
1st phalanx (*Bos*)	–	–	26.07	–	BNW-I500 (GS 2:6)
1st phalanx (*Bubalus*)	–	–	51.41	–	BNW-I500 (GS 2:10)
1st phalanx (*Bos*)	63.25	27.9	24.89	–	BNW-I500 (F1 Sloping clay surface 3:7)
1st phalanx (*Bos*)	–	25.71	–	–	BNW-I500 (F6 Test trench 3:12)
1st phalanx (*Bubalus*)	81.32	–	41.44	39.56	BNW-JI500 (GS 3:12)
1st phalanx (*Bos*)	71.62	32.71	32.95	32.78	BNW-K500 (F2 Channel 3:4)
1st phalanx (*Bubalus*)	67	39.34	36.15	36.15	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	70.36	36.39	33.91	32.18	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	70.9	40.77	37.08	35.1	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	69.95	36.65	–	–	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	75.57	34.47	33.53	34.46	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bos*)	65.94	25.48	24.24	24.24	BNW-K500 (F1 Bone Midden 3:5)

1st phalanx (*Bos*)	–	28.43	26.17	26.17	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bos*)	55.35	24.21	–	23.96	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	–	37.57	–	–	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	–	34.19	–	–	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	66.21	38.52	33.84	36.54	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	70.21	–	–	–	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	65.82	35.83	33.22	31.05	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bos*)	66.59	27.92	27.7	–	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	74.39	39.25	–	–	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	66.01	38.11	34.49	33.29	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	72.37	36.03	32.21	30.78	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	76.29	37.76	37.42	–	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	73.66	36.98	34.17	32.51	BNW-K500 (F1 Bone Midden 3:5)
1st phalanx (*Bubalus*)	70.48	39.5	38.3	36.86	BNW-K500 (F1 Pink sandy sediment 3:6)
1st phalanx (*Bubalus*)	75.63	37.81	34.19	–	BNW-T200 (GS 3:4)
1st phalanx (*Bos*)	68.76	28.05	25.91	25.91	BNW-T200 (GS 6:2)
1st phalanx (*Bubalus*)	–	–	40.75	–	BNW-TU199-200 (F5 Hard floor 3:1)
1st phalanx (*Bos*)	66.28	30.91	29.63	29.63	BNW-TU199-200 (F6 Brown sandy sediment 3:7)
1st phalanx (*Bos*)	–	27.23	–	–	BNW-U200 (GS 6:1)
1st phalanx (*Bos*)	63.19	28.4	26.36	26.13	BNW-U200 (F13 Sandy sediment 5:2)
1st phalanx (*Bubalus*)	68.27	40.71	38.51	34	BNW-V200 (GS 3:2)
1st phalanx (*Bos*)	63.35	28.37	24.37	–	BNW-V200 (GS 4:4)
1st phalanx (*Bos*)	71.76	32.69	29.34	–	BNW-V200 (GS 4:6)

1st phalanx (*Bos*)	61.76	25.73	23.67	23.08	BNW-V200 (GS 5:1)
1st phalanx (*Bos*)	64.53	25.81	25.03	24.35	BNW-V200 (GS 6:1)
1st phalanx (*Bubalus*)	58.05	37.83	36.63	35.66	BNW-V200 (F13 Hard floor 3:3)
1st phalanx (*Bos*)	71.42	31.33	27.17	27.06	BNW-V200 (F1 Pit 6:1)
1st phalanx (*Bos*)	48.99	29.77	22.6	23.03	BNW-V200 (F27 Yellow clay sediment 7:4)
1st phalanx (*Bos*)	–	23.23	–	–	BNW-Z201 (GS 4:1)
1st phalanx (*Bubalus*)	–	46.2	41.62	40.41	BNW-Z201 (GS 4:2)
1st fore phalanx *Bubalus bubalis*	65.6	35.4	37.65	–	Thailand ♀ *n* = 24 (Higham 1975)
1st fore phalanx *Bos taurus*	59.7	27.4	28.5	–	Thailand ♀ *n* = 18 (Higham 1975)
1st fore phalanx *Bos gaurus*	69.6	35.4	33.6	–	♂ (Higham 1975)
1st fore phalanx *Bos javanicus*	63.2	38	37.2	36.3	♂ (Higham 1975)

Appendix H: The teeth measurements for Muridae and Rhizomyinae Family from BNW

M^1-M^3 L	M_1-M_3 L	M_1-l_1 L	I_1 Max. D	M_1 Max. D	I^1 Max. D	M^1 Max. D	Taxon	Context
–	–	–	–	2.41	–	–	*Bandicota* sp.	BNW-G104 (GS 2:1)
–	–	–	2.88	–	–	–	*Bandicota* sp.	BNW-G104 (GS 2:4)
–	–	–	–	–	–	3.49	*Bandicota* sp.	BNW-G104 (GS 3:1)
–	–	–	–	–	2.55	–	*Bandicota* sp.	BNW-G104 (Burial 673 5:1)
–	–	–	–	–	3.03	_	*Bandicota* sp.	BNW-G104 (F3 Pottery concentration 2:3)
–	–	–	–	–	2.38	_	*Bandicota* sp.	BNW-G104 (F3 Pottery concentration 2:3)
–	–	–	–	3.11	–	–	*Bandicota* sp.	BNW-N96 (GS 6:4)
–	–	–	–	–	2.32	–	*Bandicota* sp.	BNW-N96 (GS 6:4)
–	–	–	2.25	–	–	–	*Bandicota* sp.	BNW-N96 (GS 6:4)
–	–	–	–	–	3.04	–	*Bandicota* sp.	BNW-N96 (Burial 688 6:7)
–	–	–	–	–	3.03	–	*Bandicota* sp.	BNW-N96 (Burial 688 6:7)
–	–	–	–	–	2.74	–	*Bandicota* sp.	BNW-N96 (Burial 689 6:7)
–	–	–	–	–	2.31	–	*Bandicota* sp.	BNW-N100 (GS 5:2)
–	–	–	–	2.89	–	–	*Bandicota* sp.	BNW-N100 (Burial 660 6:2)
–	–	–	–	2.49	–	–	*Bandicota* sp.	BNW-T200 (GS 1:4)
–	–	–	–	–	–	3.12	*Bandicota* sp.	BNW-U200 (GS 7:2)

–	–	–	–	2.95	–	–	*Bandicota* sp.	BNW-U200 (F9 Pottery concentration 6:3)
–	9.64	–	–	2.75	–	–	*Bandicota indica*	BNW-N96 (Burial 696 6:8)
–	9.95	–	–	3	–	–	*Bandicota indica*	BNW-N100 (Burial 654 5:2)
9.21	–	–	–	–	–	2.97	*Bandicota savilei*	BNW-O300 (Test trench 3:4)
–	9.07	7.47	–	2.64	–	–	*Bandicota savilei*	BNW-N96 (Burial 690 6:7)
–	8.37	–	–	2.33	–	–	*Bandicota savilei*	BNW-V200 (F4 Shell midden 4:3)
–	7.91	–	–	2.4	–	–	*Berylmys* sp.	BNW-G104 (GS 1:7)
6.77	–	–	–	–	–	1.58	*Niviventer* sp.	BNW-S400 (GS 4:3)
–	–	5.08	1.11	1.62	–	–	*Niviventer* sp.	BNW-T200 (Burial 663 6:1)
–	6.25	–	–	1.75	–	–	*Niviventer* sp.	BNW-T200 (Burial 663 6:1)
6.77	–	–	–	–	–	1.92	*Niviventer* sp.	BNW-U200 (F13 Sandy sediment 5:2)
–	6.67	–	–	1.75	–	–	*Niviventer* sp.	BNW-U200 (F13 Sandy sediment 5:2)
–	7.15	–	1.89	1.81	–	–	*Rattus* sp.	BNW-S400 (GS 3:6)
–	6.45	10.78	1.39	–	–	–	*Rattus* sp.	BNW-N96 (F19 Orange sandy sediment 6:7)
–	–	–	0.57	–	–	–	*Mus* sp.	BNW-P300 (GS 6:2)

–	–	–	0.89	–	–	–	*Mus* sp.	BNW-G104 (GS 2:4)
–	–	–	–	–	3.35	–	Rhizomyinae	BNW-G104 (GS 4:4)

Appendix I: The metatarsal measurements for *Bubalus* and *Bos* from BSL

Bone Element (ID)	Length	Prox.W	Dist. W	Context
Metatarsal unfused (*Bos*)	–	–	52.09	BSL-M100 (GS 3:3)
Metatarsal (*Bubalus*)	–	–	75.54	BSL-M100 (F187 Bone Midden 5:1)
Metatarsal *Bubalus bubalis*	221.9	55.0	69.7	Thailand ♀ *n* = 21 (Higham 1975)
Metatarsal *Bos gaurus*	254.5	52.5	57.75	♀ *n* = 2 (Higham 1975)
Metatarsal *Bos gaurus*	275	60.05	65.5	♂ *n* = 2 (Higham 1975)
Metatarsal *Bos javanicus*	246.33	54	55	♀ *n* = 3 (Higham 1975)
Metatarsal *Bos javanicus*	269	60.5	64.25	♂ *n* = 4 (Higham 1975)
Metatarsal *Bubalus bubalis*	221.9	55.0	69.7	Thailand ♀ *n* = 21 (Higham 1975)
Metatarsal *Bos gaurus*	254.5	52.5	57.75	♀ *n* = 2 (Higham 1975)
Metatarsal *Bos gaurus*	275	60.05	65.5	♂ *n* = 2 (Higham 1975)
Metatarsal *Bos javanicus*	246.33	54	55	♀ *n* = 3 (Higham 1975)
Metatarsal *Bos javanicus*	269	60.5	64.25	♂ *n* = 4 (Higham 1975)
Metatarsal *Bubalus bubalis*	221.9	55.0	69.7	Thailand ♀ *n* = 21 (Higham 1975)
Metatarsal *Bos gaurus*	254.5	52.5	57.75	♀ *n* = 2 (Higham 1975)
Metatarsal *Bos gaurus*	275	60.05	65.5	♂ *n* = 2 (Higham 1975)
Metatarsal *Bos javanicus*	246.33	54	55	♀ *n* = 3 (Higham 1975)
Metatarsal *Bos javanicus*	269	60.5	64.25	♂ *n* = 4 (Higham 1975)

Appendix J: The magnum measurements for *Bubalus* and *Bos* from BSL

Bone Element (ID)	Length	Max. W	Max. D	Context
Right magnum (*Bubalus*)	19.7	37.66	43.92	BSL-M100 (GS 2:5)
Left magnum (*Bubalus*)	21.5	38.11	43.32	BSL-M100 (GS 4:3)
Right magnum (*Bubalus*)	19.62	36.25	46.88	BSL-M100 (GS 5:2)
Left magnum (*Bubalus*)	21.58	41.15	44.03	BSL-M100 (GS 5:3)
Left magnum (*Bubalus*)	24.49	42.01	44.14	BSL-M100 (F187 Bone Midden 5:1)
Right magnum (*Bos*)	22.96	45.91	40.88	BSL-M100 (F187 Bone Midden 5:1)
Magnum *Bubalus bubalis*	–	36.9	39.7	♀ *n* = 15 (Higham 1975)
Magnum *Bos taurus*	–	37.4	30.5	*n* = 5 (Higham 1975)
Magnum *Bos gaurus*	–	48.4	42.3	(Higham 1975)
Magnum *Bos javanicus*	–	40.5	39	♂ (Higham 1975)

Appendix K: The first phalanx measurements for *Bubalus* and *Bos* from BSL

Bone Element (ID)	Length	Prox.W	Dist. W	Min. W	Context
1st fore phalanx (*Bos*)	69.85	36.94	32.16	32	BSL-M100 (GS 3:2)
1st phalanx (*Bubalus*)	–	–	33.93	–	BSL-M100 (GS 3:2)
1st phalanx (*Bos*)	58.72	–	–	–	BSL-M100 (GS 3:3)
1st phalanx (*Bos*)	–	–	26.26	–	BSL-M100 (GS 3:3)
1st fore phalanx (*Bubalus*)	68.39	41.96	36.12	36.12	BSL-M100 (GS 4:2)
1st fore phalanx (*Bubalus*)	77.19	40.31	42.08	39.65	BSL-M100 (GS 5:1)
1st hind phalanx (*Bos*)	76.21	35.36	31.55	31.33	BSL-M100 (GS 5:3)
1st hind phalanx (*Bos*)	57.32	26.13	–	23.88	BSL-M100 (GS 8:3)
1st hind phalanx (*Bubalus*)	73.09	37.62	35.31	35.28	BSL-M100 (F53 Pottery concentration 2:3)
1st fore phalanx (*Bubalus*)	–	44.55	–	–	BSL-M100 (F160 Pit 3:3)
1st hind phalanx (*Bos*)	–	26.29	_	23.54	BSL-M100 (F159 Pit 3:3)
1st fore phalanx (*Bubalus*)	78.13	44.45	35.14	35.14	BSL-M100 (F187 Bone Midden 5:1)
1st fore phalanx (*Bubalus*)	74.78	42	40.29	39.72	BSL-M100 (F187 Bone Midden 5:1)
1st phalanx (*Bos*)	73.06	–	34.41	–	BSL-M100 (F187 Bone Midden 5:1)
1st phalanx (*Bos*)	–	–	38.91	–	BSL-M100 (F217 Bone concentration 6:1)
1st phalanx (*Bos*)	–	–	22.12	–	BSL-M100 (F231 Pit 6:2)
1st fore phalanx *Bubalus bubalis*	65.6	35.4	35.6	–	Thailand ♀ *n* = 24 (Higham 1975)
1st fore phalanx *Bos taurus*	59.7	27.4	28.5	–	Thailand ♀ *n* = 18 (Higham 1975)
1st fore phalanx *Bos gaurus*	69.6	35.4	33.6	–	♂ (Higham 1975)
1st fore phalanx *Bos javanicus*	63.2	38	37.2	36.3	♂ (Higham 1975)

Appendix L: The metacarpal and metatarsal measurements for *Naemorhedus* from BSL

Bone Element (ID)	Length	Prox.W	Dist. W	Min. W	Context
Left metatarsal (*Naemorhedus*)	82.11	16.86	–	11.23	BSL-M100 (F160 Pit 3:3)
Left metacarpal (*Naemorhedus*)	94.55	22.16	26.35	15.44	BSL-M100 (F161 Grey clay sediment 4:1)

Appendix M: The metacarpal and metatarsal measurements for *Bubalus* and *Bos* from NHR

Bone Element (ID)	Length	Prox.W	Dist. W	Context
Right metacarpal (*Bubalus*)	–	–	74.6	NHR-H100 (F4 Pit 2:1)
Right metacarpal (*Bubalus*)	–	68.24	–	NHR-I100 (F10 Pottery concentration 2:4)
Left metatarsal (*Bos*)	–	–	52.9	NHR-H100 (GS 2:1)
Left metatarsal (*Bubalus*)	–	–	69.46	NHR-H100 (GS 3:4)
Left metatarsal (*Bubalus*)	–	–	69.65	NHR-H100 (F3 Pit 1:8)
Metacarpal *Bubalus bubalis*	183.4	62.5	74.2	Thailand ♀ *n* = 24 (Higham 1975)
Metacarpal *Bos taurus*	195.9	54.7	58.8	Thailand ♀ *n* = 18 (Higham 1975)
Metacarpal *Bos gaurus*	224.75	62.1	61	♀ *n* = 2 (Higham 1975)
Metacarpal *Bos gaurus*	228	73.5	69.75	♂ *n* = 2 (Higham 1975)
Metacarpal *Bos javanicus*	239.5	53	54.5	Java ♀ *n* = 2 (Higham 1975)
Metacarpal *Bos javanicus*	266	60	63.33	Java ♂ *n* = 3 (Higham 1975)
Metatarsal *Bubalus bubalis*	221.9	55.0	69.7	Thailand ♀ *n* = 21 (Higham 1975)
Metatarsal *Bos gaurus*	254.5	52.5	57.75	♀ *n* = 2 (Higham 1975)
Metatarsal *Bos gaurus*	275	60.05	65.5	♂ *n* = 2 (Higham 1975)
Metatarsal *Bos javanicus*	246.33	54	55	♀ *n* = 3 (Higham 1975)
Metatarsal *Bos javanicus*	269	60.5	64.25	♂ *n* = 4 (Higham 1975)
Metatarsal *Bubalus bubalis*	221.9	55.0	69.7	Thailand ♀ *n* = 21 (Higham 1975)
Metatarsal *Bos gaurus*	254.5	52.5	57.75	♀ *n* = 2 (Higham 1975)
Metatarsal *Bos gaurus*	275	60.05	65.5	♂ *n* = 2 (Higham 1975)
Metatarsal *Bos javanicus*	246.33	54	55	♀ *n* = 3 (Higham 1975)
Metatarsal *Bos javanicus*	269	60.5	64.25	♂ *n* = 4 (Higham 1975)

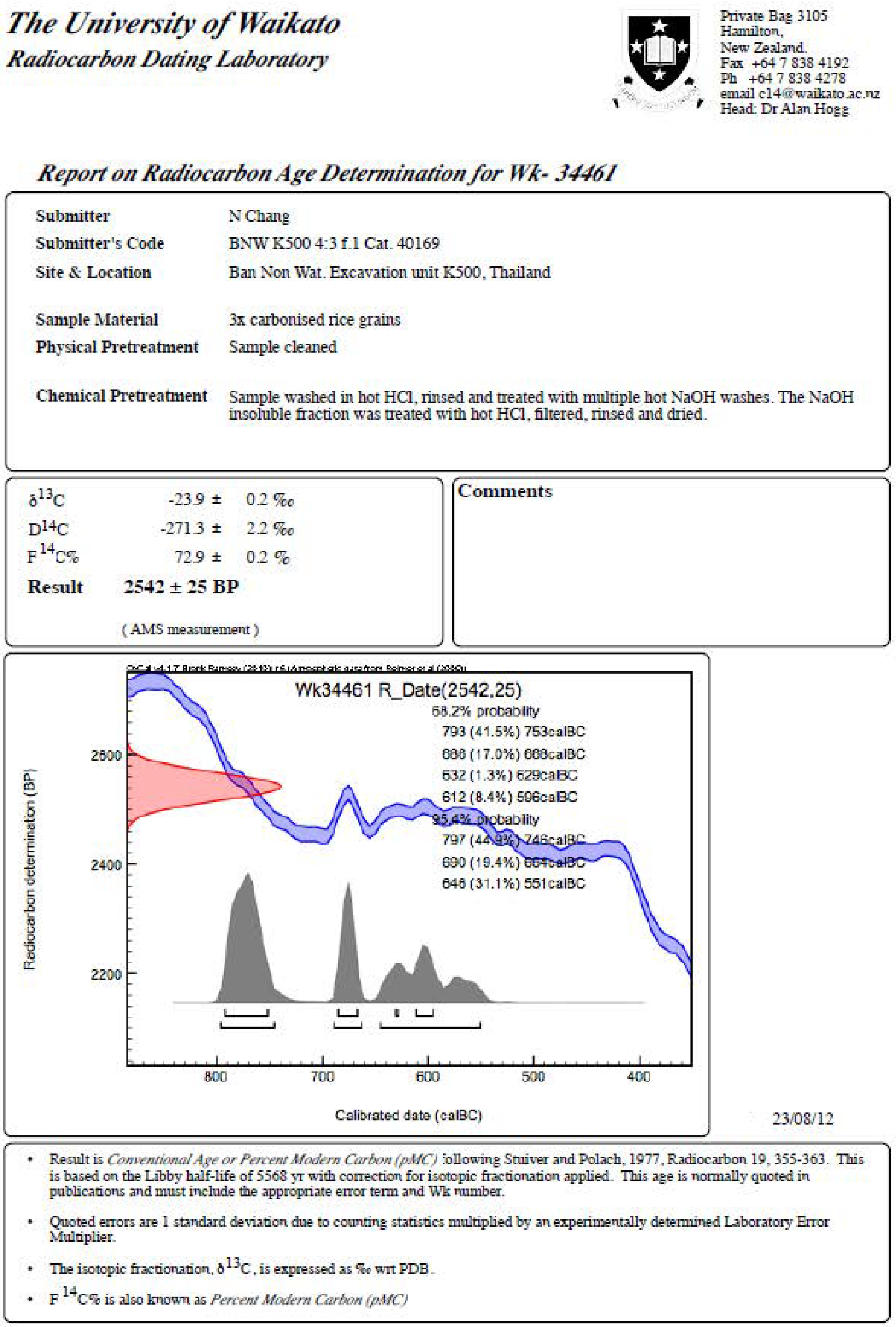
Appendix N: The magnum measurements for *Bubalus* and *Bos* from NHR

Bone Element (ID)	Length	Max. W	Max. D	Context
Right magnum (*Bos*)	21.25	43.44	43.04	NHR-I100 (GS 2:4)
Magnum *Bubalus bubalis*	–	36.9	39.7	♀ *n* = 15 (Higham 1975)
Magnum *Bos taurus*	–	37.4	30.5	*n* = 5 (Higham 1975)
Magnum *Bos gaurus*	–	48.4	42.3	(Higham 1975)
Magnum *Bos javanicus*	–	40.5	39	♂ (Higham 1975)

Appendix O: The first phalanx measurements for *Bubalus* and *Bos* from NHR

Bone Element (ID)	**Length**	**Prox.W**	**Dist. W**	**Min. W**	**Context**
1st hind phalanx (*Bubalus*)	60.61	29.45	26.87	26.45	NHR-I100 (GS 2:3)
1st fore phalanx (*Bos*)	56.28	28.05	26.45	25.07	NHR-H100 (GS 2:4)
1st phalanx (*Bubalus*)	–	–	39.58	–	NHR-H100 (GS 3:1)
1st phalanx (*Bubalus*)	–	–	33.21	–	NHR-I100 (GS 3:2)
1st fore phalanx (*Bos*)	65.92	36.12	33.93	32.77	NHR-H100 (GS 3:4)
1st fore phalanx (*Bubalus*)	81.68	39.19	39.96	29.11	NHR-HI100 (GS 3:15)
1st fore phalanx *Bubalus bubalis*	65.6	35.4	35.6	–	Thailand ♀ *n* = 24 (Higham 1975)
1st fore phalanx *Bos taurus*	59.7	27.4	28.5	–	Thailand ♀ *n* = 18 (Higham 1975)
1st fore phalanx *Bos gaurus*	69.6	35.4	33.6	–	♂ (Higham 1975)
1st fore phalanx *Bos javanicus*	63.2	38	37.2	36.3	♂ (Higham 1975)

Appendix P: Radiocarbon dates for carbonised rice grains from BNW



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Report on Radiocarbon Age Determination for Wk- 34461

Submitter	N Chang
Submitter's Code	BNW K500 4:3 f.1 Cat. 40169
Site & Location	Ban Non Wat. Excavation unit K500, Thailand
Sample Material	3x carbonised rice grains
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

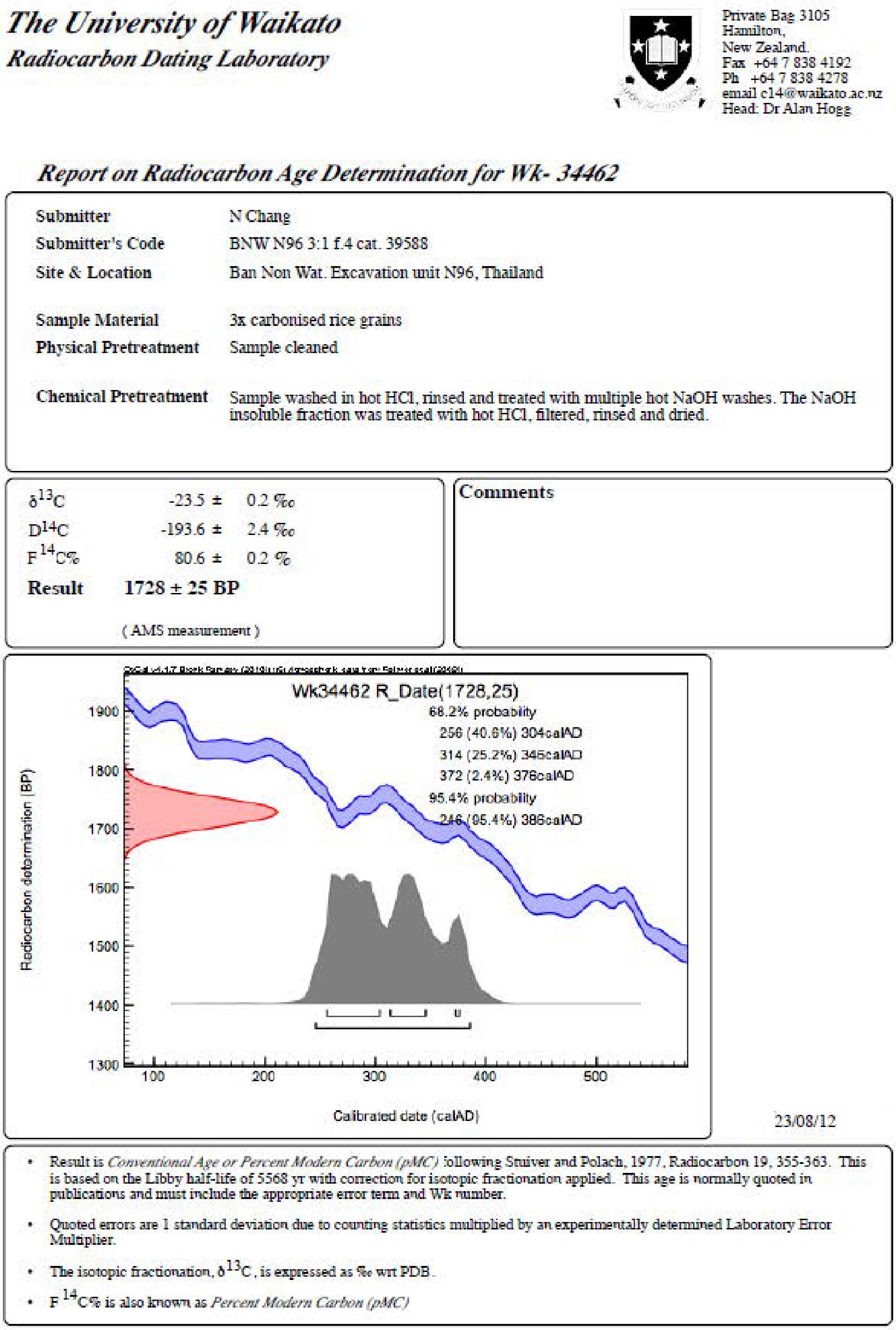
$\delta^{13}C$	-23.9 ±	0.2 ‰
$D^{14}C$	-271.3 ±	2.2 ‰
$F^{14}C\%$	72.9 ±	0.2 %
Result	**2542 ± 25 BP**	

(AMS measurement)

Comments

23/08/12

- Result is *Conventional Age or Percent Modern Carbon (pMC)* following Stuiver and Polach, 1977, Radiocarbon 19, 355-363. This is based on the Libby half-life of 5568 yr with correction for isotopic fractionation applied. This age is normally quoted in publications and must include the appropriate error term and Wk number.
- Quoted errors are 1 standard deviation due to counting statistics multiplied by an experimentally determined Laboratory Error Multiplier.
- The isotopic fractionation, $\delta^{13}C$, is expressed as ‰ wrt PDB.
- $F^{14}C\%$ is also known as *Percent Modern Carbon (pMC)*



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Report on Radiocarbon Age Determination for Wk- 34462

Submitter	N Chang
Submitter's Code	BNW N96 3:1 f.4 cat. 39588
Site & Location	Ban Non Wat. Excavation unit N96, Thailand
Sample Material	3x carbonised rice grains
Physical Pretreatment	Sample cleaned
Chemical Pretreatment	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.

$\delta^{13}C$	-23.5 ±	0.2 ‰
$D^{14}C$	-193.6 ±	2.4 ‰
$F^{14}C\%$	80.6 ±	0.2 %
Result	**1728 ± 25 BP**	

(AMS measurement)

Comments

23/08/12

- Result is *Conventional Age or Percent Modern Carbon (pMC)* following Stuiver and Polach, 1977, Radiocarbon 19, 355-363. This is based on the Libby half-life of 5568 yr with correction for isotopic fractionation applied. This age is normally quoted in publications and must include the appropriate error term and Wk number.
- Quoted errors are 1 standard deviation due to counting statistics multiplied by an experimentally determined Laboratory Error Multiplier.
- The isotopic fractionation, $\delta^{13}C$, is expressed as ‰ wrt PDB.
- $F^{14}C\%$ is also known as *Percent Modern Carbon (pMC)*